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Evaluated were longitudinal effects of a four-year unified science curriculum on high school graduates. Specific effects were grouped in areas of (1) interest in science, (2) scientific literacy, and (3) preparation for college science. The 358 subjects had graduated from high school four to seven years prior to the study. Efforts were made to control variables such as intelligence, school achievement, school setting, sex, and age. Data were obtained from high school and college transcripts and from a questionnaire. Findings indicated a general and consistent favorability for graduates from the unified science curriculum although the level of significance exceeded the arbitrary minimum in only a few isolated cases. A bibliography related to unified science is included. (BC)

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Grant No. OEG-1-7-068937-3761

EFFECTS OF A UNIFIED SCIENCE CURRICULUM ON HIGH SCHOOL GRADUATES

DECEMBER, 1967

U. S. Department of
Health, Education, and Welfare

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U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
OFFICE OF EDUCATION

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The Ohio State University
Research Foundation
Columbus, Ohio 43212

SE 005 192

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Grant No. OEG-1-7-068937-3761

John S. Richardson
Victor Showalter

December, 1967

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PREFACE

Interest in the unified science approach to science curriculum design in secondary schools has shown a steady increase during the past decade. Implementation of this interest in actual development of courses has been slow since many science educators have adopted a wait-and-see attitude. I hope that the results of this study will encourage similar curriculum developments and studies that will extend and refine the one reported herein.

I do not pretend that the expression of unified science education at The Ohio State University School is the only, or even the best, form that the unified science approach can produce. The spirit of unified science education is such that it will foster continuing evolution of the science curriculum wherever that spirit is applied.

I wish to extend my deepest gratitude to several dedicated persons who have been instrumental in developing the unified science program and this study. They are: Dr. Irwin Slesnick, Dr. John Richardson, Dr. Robert Menefee, Barbara Thompson, and Patricia Siple.

I would also like to acknowledge the counsel provided by Dr. Herbert Coon, Dr. Paul Klohr, and Dr. George Thompson of The Ohio State University College of Education. Appreciation is due also to Dr. Wallace Fotheringham and Dr. Kent Schwirian of The Ohio State University for their help with the statistical aspects of this study.

Columbus, Ohio
December 15, 1967

Victor Showalter, Principal Investigator

ABSTRACT

Possible long range effects of a four-year unified science curriculum in the high school were identified and evaluated. Specific effects were grouped in areas of (1) interest in science, (2) scientific literacy, and (3) preparation for college science. The 358 subjects had graduated from high school four to seven years prior to the study. Efforts were made to control variables such as intelligence, school achievement, school setting, sex, age, etc. Experimental treatment consisted of providing a new sequence of science courses based on interdisciplinary themes and content which replaced the traditional course sequence. Data were obtained from high school and college transcripts and from a questionnaire constructed with assistance from 50 science educators. Findings indicated a general and consistent favorability for graduates from the unified science curriculum although the level of significance exceeded the arbitrary minimum in isolated cases only. A bibliography of unified science is included.

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I - INTRODUCTION

Unified Science Education

In the past decade, revision of secondary school science curriculums has become a common involvement for science educators. Generally, this involvement has been accompanied by enthusiasm and a heightened awareness of individual professionalism. Many science teachers lost much of the reticence and resistance with which the group traditionally regarded curricular change.

The greatest effect of the national curriculum studies (PSSC, BSCS, CHEM, etc.) may well be the production of an educational climate that is sensitive to the need for continuing evolution of the secondary school science curriculum. Within this climate, science educators have begun to speculate about the potential value of alternative science curriculums that depart more radically from traditional course structures than have the products of the national curriculum studies.

One of the promising alternatives to traditional science curriculum structure is that of unified science. A unified science curriculum results from an attempt to integrate the traditional science disciplines into an educational whole. Instead of devoting an entire school year to each of biology, chemistry, and physics, a unified science curriculum incorporates aspects of each of these disciplines into each year of a sequential curriculum. Thus, graduates of schools in which a unified science curriculum is in operation have transcripts that show credits for Science I, Science II, etc., in place of traditional course titles such as chemistry, biology, etc.

The substantive content of a unified science curriculum is typically organized around broad interdisciplinary study units, each of which may be based on concept or process that permeates all scienes or on a natural phenomenon to which many sciences have contributed some understanding. Materials and subtopics are then drawn from varied disciplines to form the basis for instructional activities in each broad unit. Thus, content from experimental psychology, geology, anthropology, nuclear science, etc. can be used. These are content areas that are not ordinarily found in traditional secondary school science curriculums.

The topic of "equilibrium" can be considered as a typical conceptual theme for a unified science instructional unit. Instructional materials for the unit may be selected from several of a multitude of disciplines since "equilibrium" is a concept that is common to most science disciplines. The actual choice of instructional materials can be based on student interest and level of intellectual development.

As a consequence of the unified science approach to curriculum construction, it is possible to develop concepts in logical stages of progression rather than be limited by restriction to a traditional discipline. Thus it is possible to teach physical and chemical concepts necessary to a sophisticated understanding of life processes before the latter are taught.

The unified science curriculum does not deny the existence of specific disciplines. However, the value of specific disciplines in science has been (and is) the fostering of research traditions within which the frontiers of knowledge can be expanded. However, when the general education of all students is the principal goal of instruction, the basic assumption of unified science education is that an approach to curriculum development along strictly discipline-oriented lines is not appropriate.

The potential values of a unified science curriculum have been discussed by science educators since the 1930's, but few attempts to put theory into practice have been made. Those that have been attempted have not, until now, been followed up by appropriate research that has provided a convincing answer to the question, "Are unified science curriculums viable alternatives to traditional science curriculums?"

Some science educators have expressed doubt that any new science curriculum or course can be compared to that which it is intended to replace. The principal reason for this doubt is that each curriculum (or course) is based on subject matter that is unique to that curriculum and that the curriculum developers have arbitrarily deemed to be worthwhile. Thus each final examination is designed to test the unique aspects of the course which it accompanies. One of the most evident generalizations to come from the evaluations associated with national science curriculum studies of the 1960's is that students do best on those tests that are designed to accompany the particular course in which the student has enrolled.

Even though most science educators will agree that there are certain general objectives associated with all science instruction, tests to measure the achievement of these objectives have been virtually nonexistent. Those few that have been developed and standardized have not been widely used even though science educators verbally concur that achievement of general objectives of science instruction is more important than those objectives usually measured by end-of-course tests. The problem of developing improved science curriculums is complicated by this state of affairs.

Unified Science Education at the Ohio State University School

The first formal course in unified science at The Ohio State University School was conducted during the school year of 1959-60. The course was designated Unified Science I and replaced general science for all ninth grade students. During the following school year of 1960-61, Unified Science II replaced biology for all tenth grade students. In succeeding years Unified Science III replaced chemistry for eleventh graders, and Unified Science IV replaced physics at the twelfth grade level. Thus, the graduating class of 1963 was the first to have experienced only unified science during four years of high school.

The sequence of Unified Science I-IV continued until the University High School closed in the spring of 1967. During this time, enrollment in science was required of all students in grades nine and ten. In grades eleven and twelve science was elective.

The syllabus for unified science changed slightly during the years it was taught. The "final" form of the syllabus and miscellaneous notes on the course can be found as Appendix D. Had the University High School remained open, continued revision of the syllabus would have occurred undoubtedly. A continuing state of evolution is implicit in the spirit of unified science education.

The syllabus for unified science was the same for all students at all grade levels though teachers made deliberate efforts to individualize instructions within the classroom. An attempt to provide ability differential tracking for students in grades eleven and twelve was abandoned after a two-year trial during the school years of 1963-64 and 1964-65. Increased emphasis in the "slower" track was placed on applications of science.

Development of instructional materials for the unified science curriculum was done by the instructional staff during the school year. Thus, the lead time between writing and classroom trial was often a matter of hours.

Representative instructional materials, position papers and other pertinent documents have been collected by Showalter[1] and along with The Effectiveness of a Unified Science in the High School Curriculum by Irwin Slesnick[2] comprise a comprehensive and definitive summary of the unified science program as developed at The Ohio State University School.

The development and trial of the unified science curriculum at The Ohio State University School represents a pioneer effort. Never before had a four-year unified science curriculum been put into effect in secondary schools. In the past few years other schools have instituted similar curriculum development programs and many more seem to be on the verge of doing so. Therefore, it seems especially important and timely that the first three graduating classes of the unified science curriculum be studied in an attempt to identify some impact of their unique experience in science.

Previous Research on Unified Science Education

In the spring of 1962 Irwin Slesnick[2] studied the first three classes enrolled in unified science. At the time, the students were in grades nine, ten or eleven. Slesnick attempted to "ascertain the comparative effectiveness" of unified science instruction and traditional science instruction in achieving a "rational universe image." This objective was defined in an operational way by performance on a 65-item multiple-choice test constructed by Selsnick.

Slesnick obtained test data from seventy-eight matched pairs established among the experimental group and a control group in a nearby school. He concluded that students in the unified science curriculum had formed "a more inclusive rational image of the universe" though some qualifications in this general conclusion were cited.

Other research has, of necessity, been sharply restricted by the fact that few schools have progressed far enough in unified science development to warrant research. No research has been reported on a full four-year unified science sequence.

Morris Lerner[3] studied standard achievement test scores made by students in a conventional physics-chemistry sequence and by students in a two-year fused physics-chemistry course. The latter showed an overall superiority on the tests which were given at the end of the second year.

Purpose of This Investigation

The purpose of this investigation is to determine whether or not certain effects of a relatively long-range nature exist in individuals as a result of their having experienced a unified science curriculum rather than a traditional science curriculum in the high school.

II - METHODS

General Research Design

High school graduates that had experienced a unified science curriculum were compared to those who had experienced a traditional science curriculum. The criteria for comparison were objectives of science education that extend beyond those usually measured by end-of-course examinations and are commonly referred to as "long-range" objectives.

Two control groups were selected for comparison to the experimental group. One control came from a different school than the experimental group but was contemporary with the experimental group. The second control group came from the same school as the experimental group but graduated in the years immediately preceding the experimental group.

All data for the research were gathered in June, July, and August of 1967.

Test Populations and Samples

Three test populations were used in the research. The experimental population, designated throughout this report as "345," was composed of the graduates of The Ohio State University School of 1963, 1964, and 1965, and contained 108 individuals. During the time these classes were in grades 9-12, a unified science curriculum formed the basis for all the science offered to them.

One control population consisted of the graduates of The Ohio State University School for the years 1960, 1961, and 1962. This population is designated as "012" throughout this report and contained 108 individuals.*

A second control population consisted of the graduates of Worthington (Ohio) High School for the years 1963, 1964, and 1965, and containing approximately 800 individuals.

The samples used for the comparisons described in the "general design" were as follows:

1. The total populations of the 345 and 012 groups.

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* The use of the terms "experimental" and "control" in this report is intended to facilitate communication and may not comply exactly with meanings at the terms as they are used in the scientific disciplines.

2. Seventy-one matched pairs from the 345 and Worthington groups. The seventy-one individuals from the 345 population are designated as "Group A" throughout this report. The corresponding individuals from the Worthington population are designated as "Group B."

From the foregoing descriptions, it should be apparent that Group A is part of population 345. The relationship of the test populations and samples are shown graphically in Figure 1.

A comparison of measured IQ's of populations 345 and 012 is shown in Table I. The slight differences in the distributions are probably not significant ($X^2 = 488$, df = 6 under H_o, $.50 < p < .70$). The scores themselves are a mixture of Stanford-Binet and Wechsler test results taken from the files of the University School. For the purpose of this research, it was assumed that these tests produced equivalent scores.*

The striking similarity of the IQ's of populations 345 and 012 is not coincidental. It has long been the policy of The Ohio State University School to maintain "balanced" classes by selective admission to the school from a waiting list.

The matched pairs comprising samples A and B were those used by Slesnick[2] in studying the 345 and Worthington populations in May, 1962, while these individuals were in the ninth, tenth, or eleventh grades.** In establishing matched pairs, Slesnick used sex, grade level, age, Gamma IQ (Otis Mental Ability Test), science course background, and academic achievement in science.

Slesnick reported several coefficients of correlation as indicators of matching quality. These are shown in Table II. From these and other considerations, Slesnick felt that he had achieved near optimum matching. Slesnick did not report on how well the matched pairs of Group A and Group B represented the total populations from which they were selected.

A summary of the IQ characteristics of the experimental and control groups used in this study is presented in Table III. Several subgroups that are used in subsequent analysis of data are included in the table. The format of Table III is like that used in summarizing most of the findings in a later section.

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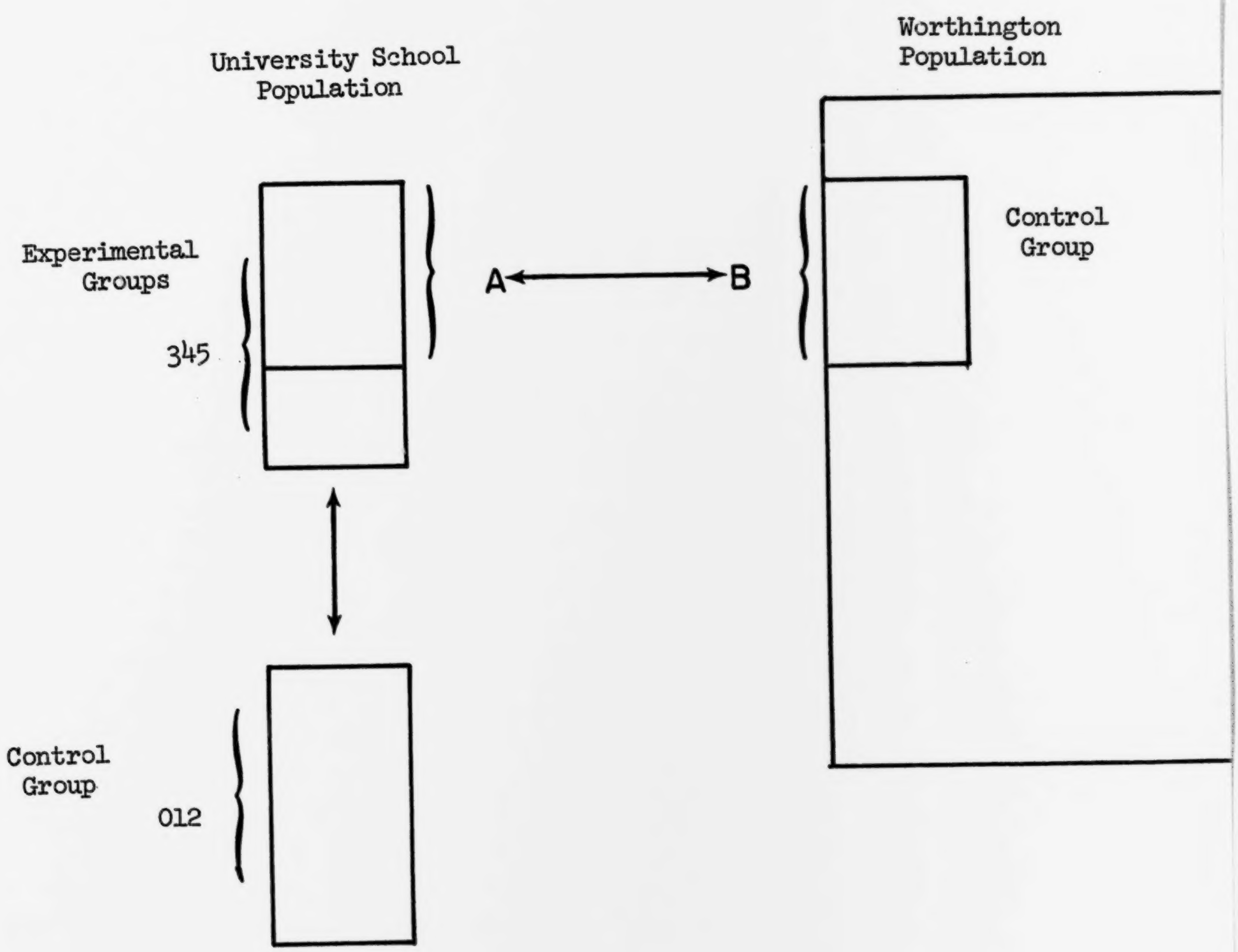
* This assumption was substantiated in a private communication from Dr. D. C. Smith, Department of Psychology, The Ohio State University.

** Seventy-eight matched pairs were used in the Slesnick study. Seven of these were dropped because one individual from each of the seven pairs transferred to another school before graduation.

FIGURE 1

Relationships of Test Populations and Samples



Worthington Population
University School Population
Experimental Groups
345
A
B
Control Group
Control Group
012

TABLE I - Distribution of IQ Scores in University School Experimental (345) and Control (012) Groups

IQ Score*	Number of Individuals	
	345	012
> 139	18	15
130-139	12	12
120-129	30	36
110-119	26	26
100-109	11	11
90-99	7	8
< 90	4	0
Total	108	108
Maximum Score	160	164
Minimum Score	69	92

* Stanford-Binet or Wechsler IQ scores

TABLE II - Correlation between Matched-Pairs of Groups A and B for Selected Characteristics*

Characteristic	Correlation (C)
Raw Score-_Otis_ _Mental_ _Ability_ _Test_	.998
Gamma IQ	.995
Age (months)	.892
Academic Achievement in science (grades)	.877

* adapted from Slesnick

TABLE III - IQ Characteristics of Experimental and Control Groups

Group	n	IQ* Range	Mean IQ*	Under H_0, p	Group	n	IQ** Range	Mean IQ**
345-All	108	69-160	121.1		A-All	71	92-140	116.2
012-All	108	92-164	122.3		B-All	71	92-139	116.6
345-Boys	56	82-160	122.6		A-Boys	38	92-140	116.6
012-Boys	60	92-164	124.4		B-Boys	38	93-139	116.9
345-Girls	52	69-151	119.4		A-Girls	33	95-136	115.8
012-Girls	48	96-152	119.8		B-Girls	33	96-135	116.1
345-Top Third	39	127-160	138.3		A-Top Third	23	125-140	130.0
012-Top Third	38	127-164	137.5	$>.10^+$	B-Top Third	23	125-140	129.7
345-Middle Third	32	117-126	120.6		A-Middle Third	26	112-124	116.0
012-Middle Third	32	117-126	121.6	$>.10^+$	B-Middle Third	26	112-124	116.5
345-Botton Third	37	69-116	103.4		A-Bottom Third	22	92-111	102.0
012-Botton Third	38	92-116	107.7	$>.10^+$	B-Middle Third	22	92-111	102.9

* Stanford-Binet or Wechsler Test Scores

** Otis Quick Scoring Gamma IQ

+ Determined by Mann-Whitney U Test

Any two school settings differ in time and/or space. In this study, the 345 group differed in time from the 012 group but occupied the same space (i.e., school). The A group differed in space from the B group but the two groups were contemporary. Nevertheless, there are numerous similarities in the school settings for each pair of groups. Specific details of the school settings are described in Appendix C.

For the purposes of this investigation, it was assumed that the unique treatment of the experimental groups is the principal variable and that no other systemic variables were present which could have had a great effect on the results of the study.

Criteria for Comparison

Three general criterion areas for comparing the experimental groups to the control groups were established. They were:

I. Interest in science

II. Achievement of scientific literacy

III. Preparation for college courses in science

These three general areas were established as a result of the investigator's interaction with numerous science teachers during the past five years. Many interactions occurred as a direct consequence of the investigator presenting a talk, paper, or article describing unified science curriculum developments to audiences of science educators. Other interactions occurred by way of the literature of science education from the past two decades.

Though the three general criterion areas are related, they served as convenient categories for the research that was done.

Each category was more or less operationally defined by the criterion measures devised for each of them.

Criterion Measures

1. It was assumed that an individual's interest in science could be measured by:

1. The number of science courses elected in high school.
2. The individual's perception of his own interest in science.
3. The number of hours of science courses elected in the freshman year of college by those individuals entering college in the year after graduation from high school.

4. The individual's perception of his own major intent when he entered college.

II. It was assumed that achievement of certain aspects of scientific literacy could be measured by obtaining individual reactions to appropriate items in a specially constructed paper-and-pencil instrument. This assumption was strengthened by invoking the assistance of a relatively large panel of science educators in constructing the instrument. The panel was selected, at random, from the membership of the National Association for Research in Science Teaching.

The Abridged Scientific Literacy Instrument (ASLI) that was eventually used in obtaining data consisted of twenty-two items and can be found in Appendix B. Details of the procedures used to devise the ASLI can be found in Appendix A.

Each of the items of the ASLI force the subject to respond on a seven-point scale. The subject's response on each item was compared to the mean response of the panel and the difference calculated. Summing the differences for all items enabled a "distance" score to be assigned to each subject. Thus, the smaller the score the closer the subject was to the mean response of the panel.

III. It was assumed that adequacy of an individual's preparation for college science courses could be measured by:

1. The grades that the individual achieved in first-year college science courses.

2. The individual's perception of his own preparation for college science courses.

First-year college science courses were taken as those in which the individual enrolled during the first three quarters, or its equivalent, of college attendance in the year immediately following high school graduation. If a student dropped out or flunked out before the expiration of three quarters, he was still considered to have been enrolled for "one year" for purposes of analysis.

All data for grades in college science courses was recorded directly from official transcripts. Grades were recorded in semester hours on a four-point scale on which A = 4, B = 3, etc.

First-year college science courses were categorized into biological science, physical science, or social science prior to analysis. Actual course titles and the categories into which they were placed can be found in Appendix F.

The colleges and universities attended by individuals were categorized according to "selectivity" as specified by Cass and Birnbaum.[4] Five categories, ranging from "non-selective" to "most selective," were used. A listing of specific colleges and the categories in which they were placed appears in Appendix G.

Data Gathering

All data were gathered in June, July, and August, 1967. Principal sources of data and the information obtained from these sources were:

1. Official high school permanent records: High school science courses elected by individuals.
2. Short questionnaire to subjects: College (if any) entered, date of entry, and major intent at the time of entry. (Also, granted permission to obtain college transcripts.)
3. Official college transcript: Number of hours of science elected, specific science courses elected in the freshman year, and grades for these courses.
4. Long questionnaire: Scientific literacy score on ASLI, perception of indvidual interest in science, and perception of individual preparation for college.

Special efforts were made to obtain complete data on all subjects. The task was complicated by the wide dispersal of the subjects and the time interval since high school graduation. Table IV summarizes the percentage of possible responses that were actually obtained.

A special effort was made to avoid referring to the science education orientation of the study when communicating with the subjects.

Further details of the data-gathering processes can be found in Appendix E along with replicas of the communications used in the process.

Data Treatment and Statistical Considerations

The data from the various sources were organized into three major divisions corresponding to the criterion areas of interest in science, achievement of scientific literacy, and preparation for college science. Within each major division, certain data sources such as questionnaries and transcripts led to naturally distinct collections of data.

Three items from the long questionnaire (23, 24, and 26) that pertained to self-perceived interest in science were combined to produce one "interest score." This was done to produce one measure of interest that would be more valid than if the items were analyzed separately.

TABLE IV - Percentage of Different Samples for Which Data Sources Were Obtained

Data Source	Sample 345 (n = 108)	 012 (n = 108)	 A (n = 71)	 B (n = 71)
High School Transcript	(108) 100%	(108) 100%	(71) 100%	(71) 100%
Small Questionnaire	(101) 94%	(100) 93%	(68) 95%	(64) 90%
College Transcript	(88) 81%	(86) 80%	(66) 93%	(50) 70%
Large Questionnaire	(96) 89%	(85) 79%	(68) 96%	(53) 75%

A similar combination of responses to four items (29, 32, 33, and 34) pertaining to self-perceived preparation for college science was made to produce one "college preparation score."

In analyzing data on the intended field of major specialization when individuals entered college, a question arose as to whether or not "mathematics" should be categorized with the sciences. To answer this question, five interviews were conducted by telephone or in person with individuals that had indicated an intent to major in mathematics on the short questionnaire. Three of these individuals expressed the position that their mathematics major was a convenient undergraduate "parking place" until they could decide on a specific field of science as their ultimate professional specialization. On the basis of these comments, mathematics was arbitrarily categorized as a science major as opposed to a non-science major.

For each distinct collection of data, subgroupings of the test samples were made according to sex and IQ triad. These subgroupings follow the precedent set by Slesnick in his previous study of group A and B. Thus, with the total group, there are six comparisons made within each distinct collection of data.

The number of subjects in the various subgroups differed from one comparison to another for several reasons. For some individuals in the 345 and 012 groups, some data were unavailable and some were unusable. Unusuable data were usually caused by incomplete responses to one or more items in a series of items that was used to produce a single score as with that previously described as an "interest score."

For the A and B groups (matched pairs) both members of each pair had to provide valid data before either could be used. The over-all effect has been to produce data that have a variable "n" from one table to another.

In all categories for which data were collected, the usual procedure for analysis was:

1. Compute a mean for the criterion measure for each principal group and for each subgroup.
2. Calculate the difference between the means of corresponding experimental and control groups.
3. Perform a statistical test of significance to determine the probability (p) that data for corresponding groups differed only by chance.
4. Test, in effect, a null hypothesis (H_o) that no difference existed between the data for corresponding groups. In order to reject null hypotheses, an arbitrary level of significance (α) was established as 0.05.

All p's reported are for two-tailed tests although a rationale could possibly be developed that would lead to the use of one-tailed tests, at least in certain cases. For example, one of the purposes for developing a unified science curriculum could be argued to be that of increasing student interest in science. If this viewpoint were granted, then a directional hypothesis could be stated and a one-tailed test of significance would be appropriate. Similar reasoning could be applied to data involving scientific literacy but probably not to those data involving college preparation in science since the latter was never explicitly mentioned in reasons given for developing a unified science curriculum.

The choice of two-tailed tests of significance for analysis of data in the research reported was made ultimately on the basis of conservatism. The tendency toward conservatism in rejecting null hypotheses was a general policy throughout the study and is reflected in other statistical considerations.

Nonparametric statistical tests were used almost exclusively throughout the data analysis. The decision to use nonparametric tests as opposed to parametric tests was based on several specific considerations. First, the assumption requiring normally distributed samples that is necessary for using parametric tests could not be warranted. The number of individuals in some subgroups was less than ten and the use of matched pairs was further argument against the assumption of normalcy.

Further argument of the choice of nonparametric over parametric tests was found in the nature of the data. Often, the data were essentially ordinal as in the case of the number of science courses elected or in the case of scaled responses to questionnaire items. Parametric tests require data that are expressed on an interval scale.

The few assumptions necessary to use nonparametric tests such as that of underlying continuity, could be made in all cases.

All nonparametric tests were performed as recommended and described by Siegel.[6] Specific statistical tests are identified with all tabular data that appear in this report.

Actual calculated p's are reported in tabular data wherever feasible because readers may be interested in certain results that exceed, but are close to, the arbitrary level of significance.

All computations were performed from formalized worksheets with the aid of an electric calculator.

Questionnaire Reliability

A test-retest method was used to establish a measure of reliability for the long questionnaire. The individuals were selected, at random, from the first 25 that returned long questionnaires. Exactly two weeks after the first long questionnaire had been received from each of the selected individuals, a second long questionnaire was sent with a request that it be completed. The request was made without reference to the reason for seeking a second response. The letter sent to the ten individuals is reproduced in Appendix E.

An arbitrary time limit of two weeks for return of the second long questionnaire prior to analysis was set. No follow-up efforts to obtain a response were made. Eight replies were received within the time limit.

Six of the responses were from individuals who had entered college in the year after graduation from high school. Two of the responses were from individuals who had not entered college. Three individuals responded from each of the 345 and 012 sample groups. Two individuals responded from the B sample group.

A Pearson product-moment correlation coefficient was computed between the first and second responses to questionnaire items 1-22 which comprised the Abridged Scientific Literary Instrument (ASLT) portion of the questionnaire. An r of 0.76 was obtained.

A Pearson product-moment correlation coefficient was computed also for questionnaire items 23-34. This group of items comprised the section on individual perceptions of interest in science and preparation for college science. For these, an r of 0.83 was obtained.

For items 1-22, 20% of the second responses differed from the first response by more than one point and 7% varied from the first response by more than two points.

For items 23-34, 13% of the second responses differed from the first response by more than one point and 1% varied from the first response by more than two points.

III - FINDINGS

Interest in Science

Years of Science Elected in Grades 9-12

Table V summarizes the years of science elected by the various test groups. In all comparisons the experimental groups enrolled in more courses than did the control groups.

In all cases but one the difference was significant at the 0.05 level of significance or better.

In the one exception, the top IQ triad of the matched pairs, the level of insignificance just misses the arbitrary 0.05 level. In this group, the control group enrolled in a mean 3.74 years of science. This is very high when one considers that 4.00 is a maximum and thus, the difference between it and the experimental group is minimized. In other words, there is not much room for improvement.

The difference between experimental and control sub-groups was noticeably greater for girls than it was for boys. The traditional tendency for boys to elect more science that girls seems to be substantiated by the data.

An alternative way of looking at the number of years of science that were elected by the experimental and control groups is presented in Tables VI and VII. In these tables the percent of graduates that elected three and four years of science are recorded for experimental and control subgroups.

In these comparisons, the differences between experimental and control groups appear to be even greater than when the means were compared. In all cases the proportions of the experimental students enrolled in science for at least four or three years exceeded that of the control students.

The statistical probabilities that these differences are due to chance are well below the arbitrary 0.05 level.

Science Hours Elected During First Year of College--All Sciences

Table VIII summarizes the mean hours of science elected by experimental and control groups. All science courses in the physical, biological and social sciences, as categorized previously, are included. The means are reported as semester hours.

TABLE V - Years of High School Science Elected in Grades 9-12 by Experimental and Control Groups

Group	n	Mean Years	Diff.	Group	n	Mean Years	Diff.	Under H_0, p
345-All	108	3.59	+ 0.82	A-All	71	3.76	+ 0.56	< .001
012-All	108	2.77		B-All	71	3.20		
345-Boys	56	3.79	+ 0.82	A-Boys	38	3.84	+ 0.34	< .01
012-Boys	60	2.97		B-Boys	38	3.50		
345-Girls	52	3.39	+ 0.86	A-Girls	33	3.67	+ 0.79	< .01
012-Girls	48	2.53		B-Girls	33	2.88		
345-Top Third	39	3.75	+ 0.69	A-Top Third	23	3.96	+ 0.22	.06**
012-Top Third	38	3.06		B-Top Third	23	3.74		
345-Mid Third	32	3.42	+ 0.96	A-Mid Third	26	3.69	+ 0.46	.02 < p < .05
012-Mid Third	32	2.46		B-Mid Third	26	3.23		
345-Bottom Third	37	3.35	+ 0.69	A-Bottom Third	22	3.64	+ 1.05	< .01
012-Bottom Third	38	2.66		B-Bottom Third	22	2.59		

* Wilcoxon Matched-Pairs Signed Ranks test

** Sign test used instead of Wilcoxon test because of small n that showed difference in years of science elected

TABLE VI - Percent of Experimental and Control Groups That Elected
Four Years of Science in Grades 9-12

Group	n	%	Under H_0, p*	Group	n	%
345-All	108	67.6		A-All	71	80.3
012-All	108	18.5	$< .001$	B-All	71	39.5
345-Boys	56	82.1		A-Boys	38	86.9
012-Boys	60	30.0	$< .001$	B-Boys	38	57.9
345-Girls	52	51.9		A-Girls	33	72.7
012-Girls	48	4.2	$< .001$	B-Girls	33	15.1
345-Top Third	39	79.5		A-Top Third	23	95.7
012-Top Third	38	34.2	$< .001$	B-Top Third	23	73.9
345-Mid Third	32	78.2		A-Mid Third	26	76.9
012-Mid Third	32	9.4	$< .001$	B-Mid Third	26	38.5
345-Bottom Third	37	45.9		A-Bottom Third	22	68.2
012-Bottom Third	38	10.5	$.001 < p < .01$	B-Bottom Third	22	4.5

* Chi Square test for two independent samples

TABLE VII - Percent of Graduates That Elected Three or More Years of Science in Grades 9-12

Group	n	%	Under H_0, p*	Group	n	%
345-All	108	92.6		A-All	71	95.8
012-All	108	60.2	< .001	B-All	71	81.7
345-Boys	56	98.2		A-Boys	38	97.4
012-Boys	60	68.4	< .001	B-Boys	38	92.1
345-Girls	52	86.5		A-Girls	33	93.9
012-Girls	48	50.0	< .001	B-Girls	33	69.7
345-Top Third	39	94.9		A-Top Third	23	100.0
012-Top Third	38	73.7	.02 < p - .05	B-Top Third	23	100.0
345-Mid Third	32	93.8		A-Mid Third	26	92.3
012-Mid Third	32	50.0	< .001	B-Mid Third	26	84.6
345-Bottom Third	37	89.2		A-Bottom Third	22	95.4
012-Bottom Third	38	55.3	.001 < p < .01	B-Bottom Third	22	59.1

* Chi Square test for two independent samples

TABLE VIII - Mean Hours of All Science Elected during First Year of College by Experimental and Control Groups

Group	n	Mean	Diff.	Under H$_o$, p*	Group	n	Mean	Diff.	Under H$_o$, p**
345-All	88	7.18	+ 1.12	.24	A-All	45	7.02	- .29	.84
012-All	86	6.06			B-All	45	7.31		
345-Boys	44	7.16	+ 1.16	.40	A-Boys	21	6.62	+ .10	.89
012-Boys	45	6.00			B-Boys	21	6.52		
345-Girls	44	7.20	+ 1.08	.45	A-Girls	24	7.38	- .82	.65
012-Girls	41	6.12			B-Girls	24	8.00		
345-Top Third	32	7.78	+ 0.51	.85	A-Top Third	17	7.18	- .82	.70
012-Top Third	30	7.27			B-Top Third	17	8.00		
345-Mid Third	30	6.33	+ 1.44	.64	A-Mid Third	15	7.20	-1.00	.72
012-Mid Third	27	4.89			B-Mid Third	15	8.20		
345-Bottom Third	26	7.35	+ 1.38	.38	A-Bottom Third	13	6.62	+1.24	.45
012-Bottom Third	29	5.97			B-Bottom Third	13	5.38		

* Mann-Whitney U test

** Wilcoxon Matched-Pairs Signed-Ranks test

There apparently is no systematic difference between the experimental and control groups that achieve the arbitrary 0.05 level of significance.

Comparisons of only those hours of science categorized as "physical" and "biological" are presented in Table IX. Overall there seems to be a general favorability for the experimental groups although the arbitrary 0.05 level of significance is achieved for differences between only two subgroups.

Self-perception of Interest in Science

Three items (23, 24, and 26) of the long questionnaire were combined to produce an interest score. The results are shown in Table X. Although the general impression of the tabular data is one of greater interest among the experimental groups, statistical significance at the arbitrary 0.05 level was forthcoming for only one of the sub-group comparisons.

It should be recalled that the statistical tests used were all two-tailed. Had they been one-tailed, that is, if it had been hypothesized that greater interest in science should have resulted from the experimental treatment, then the difference between the 345 and 012 groups would have been significant.

The data reflect interest patterns that are consistent with traditional expectations. That is, greater interest in science is generally associated with boys and with higher IQ triads.

Responses to three "interest" items contained in the long questionnaire and not combined in the "interest in science" score (Table X) are summarized separately in Table XI.

The responses to item 25 (How has your interest in science changed since you left high school?) shows that all groups felt that their interest in science had increased. However, the control groups felt that their interest had increased slightly more than did the experimental groups.

The small, and apparently insignificant, differences can be interpreted two ways in terms of the high school science courses of the experimental and control groups. In one interpretation, the level of science interest of the experimental groups at graduation from high school was greater than for the control groups, thus permitting relatively less increase in interest after graduation.

The second interpretation possible is to assume that all groups left high school with the same level of interest and that the control groups actually did increase interest more than did the experimental

TABLE IX - Mean Hours of Physical and Biological Science Elected during First Year of College by Experimental and Control Groups

Group	n	Mean	Diff.	Under H_o, p*	Group	n	Mean	Diff.	Under H_o, p**
345-All	87	4.97	+ .47	.59	A-All	46	4.78	+ .61	.38
012-All	84	4.50			B-All	46	4.17		
345-Boys	43	6.53	+ 2.15	.05	A-Boys	21	6.62	+ 1.33	> .05
012-Boys	45	4.38			B-Boys	21	5.29		
345-Girls	44	3.43	- 1.21	.21	A-Girls	25	3.24	0	> .05
012-Girls	39	4.64			B-Girls	25	3.24		
345-Top Third	32	6.38	+ .57	.84	A-Top Third	17	6.12	+ .36	> .05
012-Top Third	31	5.81			B-Top Third	17	5.76		
345-Mid Third	29	4.24	+ .74	.41	A-Mid Third	15	3.47	- .93	> .05
012-Mid Third	24	3.50			B-Mid Third	15	4.40		
345-Bottom Third	26	4.04	+ .11	.80	A-Bottom Third	14	4.57	+ 2.57	.05
012-Bottom Third	29	3.93			B-Bottom Third	14	2.00		

* Mann-Whitney U test

** Wilcoxon Matched-Pairs Signed-Ranks test

TABLE X - Self-Perceived Interest in Science by Experimental and Control Groups

(Combined score on Long Questionnaire items 23, 24, and 26. Possible range of scores = 3-21)

Group	n	Mean	Diff.	Under H_o, p*	Group	n	Mean	Diff.	Under H_o, p**
345-All	93	12.3			A-All	50	12.7		
012-All	82	11.3	+ 1.0	.09	B-All	50	11.8	+ 0.9	.13
345-Boys	47	12.9			A-Boys	24	12.8		
012-Boys	49	12.1	+ 0.8	.21	B-Boys	24	13.0	- 0.2	.92
345-Girls	46	11.6			A-Girls	26	12.7		
012-Girls	33	10.5	+ 1.1	.21	B-Girls	26	10.3	+ 2.4	.14
345-Top Third	33	12.6			A-Top Third	19	14.7		
012-Top Third	29	12.4	+ 0.2	.74	B-Top Third	19	12.4	+ 2.3	$.05 > p > .02$
345-Mid Third	30	12.7			A-Mid Third	15	12.0		
012-Mid Third	25	11.5	+ 1.2	.31	B-Mid Third	15	11.9	+ 0.1	$> .05$
345-Bottom Third	30	11.9			A-Bottom Third	16	11.3		
012-Bottom Third	28	10.1	+ 1.8	.15	B-Bottom Third	16	11.3	0	$> .05$

* Mann-Whitney U test

** Wilcoxon Matched-Pairs Signed-Ranks test

TABLE XI - Responses to Miscellaneous Questions Related to Interest in Science by Experimental and Control Groups

(Long questionnaire items: 25, 27, and 28)

	Group	n	Mean	Diff.	Under H_o; p*	Under H_o; p**
Item 25. How has your interest in science changed since you left high school? (1 = great decrease, 7 = great increase)	345-All	95	4.22			
	012-All	84	4.44	-0.22	0.68	
	A-All	49	4.37			
	B-All	49	4.47	-0.10		0.74
Item 27. What proportion of the books that you have read of your own choosing in the past two years has been devoted to scientific topics? (1 = none, 7 = all)	345-All	95	2.66			
	012-All	86	2.43	+ 0.23	0.20	
	A-All	50	2.76			
	B-All	50	2.70	+ 0.06		0.59
Item 28. Other than from books, do you feel that the knowledge you have gained about science during the past year has come mainly from reading popular publications (e.g., newspapers and *Time* magazine) of from technical publications (e.g., *The American Journal of Botany*)? (1 = completely popular, 7 = completely technical)	345-All	93	2.78			
	012-All	84	2.76	-0.02		
	A-All	48	2.79			
	B-All	48	2.94	-0.15		.63

* Mann-Whitney U test

** Wilcoxon Matched-Pairs Signed-Ranks test

groups. Assuming that the large number of science courses elected in high school indicates greater interest at that time, the first interpretation is favored.

The responses to item 27 (What proportion of the books that you have read of your own choosing in the past two years has been devoted to scientific topics?) indicate that the experimental groups felt that a greater (but statistically insignificant) proportion of their free choice reading had been devoted to scientific topics.

Responses to items 28 (Other than from books, do you feel that the knowledge you have gained during the past year has come mainly from reading popular publications or from technical publications?) show no clear difference favoring either the experimental or control groups.

Major Intent When Individuals Entered College

Table XII summarizes the areas of major interest reported by subjects and categorized according to the schedule reported previously. Although both experimental groups showed a greater proportion of individuals intending to major in science, the difference is not significant at the arbitrary 0.05 level of significance.

It should be recalled that the statistical tests of significance are two-tailed tests. If one-tailed tests were applied, the difference between the A and B groups would be significant at the arbitrary 0.05 level.

A categorical breakdown of the individuals that intended to major in science is presented in Table XIII. From this, it is apparent that whatever numerical superiority in science major intent is shown by the experimental groups is concentrated in two categories: mathematics and social science. Whatever numerical inferiority in science major intent that is shown by the experimental groups is concentrated in the medical and biological science categories.

Scientific Literacy

Summary comparisons of experimental and control group results on the Abridged Scientific Literacy Instrument (ASLI) are shown in Table XIV. It should be noted that the reported means are based on the difference of each individual from the panel mean answers for each item in the ASLI. Thus, the lower of two reported means indicated that there was closer agreement with the panel.

For example, in comparing the total A and B groups, the mean of the individual A group differences from the mean panel response was

TABLE XII - Individuals Intending to Major in Science When They Entered College

Major Intent	Number in Sample			
	345	012	A	B
Science	41 (44%)	29 (32%)	28 (50%)	19 (34%)
Non-Science	44 (47%)	45 (49%)	24 (43%)	33 (59%)
Undecided	9 (9%)	17 (19%)	4 (7%)	4 (7%)
Total	94 (100%)	91 (100%)	56 (100%)	56 (100%)
	Under H_o: $.10 < p < .20$*		Under H_o: $p = .08$**	

* Chi square test for two independent samples

** Sign test

TABLE XIII - Individuals Intending to Major in Different Areas of Science When They Entered College

Category	Number in Sample			
	345	012	A	B
Engineering	4	3	3	3
Physical Science	4	4	3	4
Medical Science	5	10	3	5
Social Science	11	1	7	2
Mathematics	16	5	11	2
Biological Science	1	5	1	2
Other Science	0	1	0	1
Total	41	29	28	19

TABLE XIV - Differences from the Panel Mean on the Abridged Scientific Literacy Instrument (ASLI) by Experimental and Control Groups

Group	n	Mean	Diff.	Under H_0, p*	Group	n	Mean	Diff.	Under H_0, p**
345-All	96	29.7			A-All	51	29.2		
012-All	85	27.4	+ 2.3	.007	B-All	51	31.4	-2.2	.10
345-Boys	48	29.8			A-Boys	25	29.6		
012-Boys	51	27.7	+ 2.1	.67	B-Boys	25	30.8	-1.2	.74
345-Girls	48	29.6			A-Girls	26	28.8		
012-Girls	34	27.0	+ 2.6	.05	B-Girls	26	31.8	-3.0	.11
345-Top Third	34	27.5			A-Top Third	19	26.6		
012-Top Third	30	24.6	+ 2.9	.03	B-Top Third	19	29.2	-2.6	.26
345-Middle Third	31	29.9			A-Middle Third	16	31.4		
012-Middle Third	27	28.4	+ 1.5	.29	B-Middle Third	16	30.1	+ 1.3	.29
345-Bottom Third	31	32.1			A-Bottom Third	16	30.2		
012-Bottom Third	28	29.5	+ 2.6	.11	B-Bottom Third	16	35.1	-4.9	.02

* Mann-Whitney U test

** Wilcoxon Matched-Pairs Signed-Ranks test

29.2. At the same time individuals in the B group differed from the panel by an average of 31.4. Thus, the A group was closer to the jury than was the B group.

The pattern of comparisons is rather striking and in some ways self-contradictory. The A group, overall, excelled the B group though the difference was not within the arbitrary 0.05 level of confidence for a two-tailed test. However, if a one-tailed test could be justified, the difference is just within the arbitrary 0.05 level of significance.

The 345 group, overall, differed more from the jury than did the 012 group. In this case the difference was significant well within the arbitrary 0.05 level of confidence.

Looking at the data for the subgroupings of the principal test populations shows some interesting patterns. Generally, higher IQ groups agree more closely with the jury than do lower IQ groups. Girls, surprisingly, show better agreement with the jury than do boys of the same test population in three of four cases even though the differences are small.

College Preparation

Individual Perception of College Preparation in Science

Table XV summarizes individuals' perception of their own pre-college preparation in science as measured by the combined score of four items (29, 32, 33, and 34) on the Long Questionnaire. The mean scores for each major group and for each subgroup are on a scale that could range from a low of four to a high of 28.

Comparison of both major experimental groups to the corresponding control groups showed a favorability for the experimental group. However, none of the differences was statistically significant at the arbitrary 0.05 level of significance. The difference between the 345 and 012 groups just misses achieving the required level of significance.

Most subgroups show a favorability for the experimental groups though none of the differences is statistically significant at the arbitrary 0.05 level of significance. As with the major groups, a few of the differences come close to achieving the required level of significance.

Generally the mean scores are higher for the higher IQ triads among the subgroups. The only exception to this pattern is for the lowest triad of the A sample.

TABLE XV - Individual Perception of College Preparation in Science by Experimental and Control Groups

(Total Score of items 29, 32, 33, and 34. Possible Scores: 4-28)

Group	n	Mean	Diff.	Under H_o, p*	Group	n	Mean	Diff.	Under H_o, p**
345-All	82	19.01			A-All	35	19.26		
012-All	76	17.42	+ 1.59	0.06	B-All	35	18.06	+ 1.20	.28
345-Boys	48	19.36			A-Boys	17	18.92		
012-Boys	51	18.33	+ 1.03	0.36	B-Boys	17	19.59	- 0.67	> .05
345-Girls	48	18.70			A-Girls	18	19.56		
012-Girls	34	16.40	+ 2.30	0.07	B-Girls	18	16.61	+ 2.95	> .05
345-Top Third	29	20.28			A-Top Third	16	20.75		
012-Top Third	28	19.25	+ 1.03	0.37	B-Top Third	16	20.00	+ 0.75	> .05
345-Middle Third	27	19.56			A-Middle Third	11	19.81		
012-Middle Third	25	17.28	+ 2.28	0.08	B-Middle Third	11	16.00	+ 3.81	> .05
345-Bottom Third	26	17.04			A-Bottom Third	8	15.50		
012-Bottom Third	23	15.74	+ 2.30	0.40	B-Bottom Third	8	17.00	- 1.50	> .05

* Mann-Whitney U test

** Wilcoxon Matched-Pairs Signed-Ranks test

Responses to two items in the "college preparation" section of the Long Questionnaire were not combined in the "college preparation in science" score (Table XV) and are summarized in Table XVI.

Responses to item 30 (How did the difficulty of your first science course in college compare to the difficulty you had expected?) show that the experimental groups felt that the first college science course was less difficult than did the control groups. However, the differences are not significant at the .05 level of significance. All groups reported that the first college science course was slightly less difficult than had been expected.

Responses to item 31 (How did your actual level of interest in your first college science course compare to the interest you had expected?) show that there was practically no difference between experimental and control groups. All groups reported that interest was slightly greater than had been expected.

First Year College Science Grades

Table XVII summarizes data for all experimental and control groups and includes all science grades. The mean grades reported are derived from point/hour ratios for individual subjects.

Generally, the 345 experimental group had higher grades than did the 012 control group. However, none of the differences is significant at the arbitrary 0.05 level of significance.

Comparison of the data for the A and B groups shows that the control group generally achieved higher grades than did the experimental group. Differences for two of the subgroups ("boys" and "top IQ triad") were significant at the arbitrary 0.05 level of confidence although the difference between the total groups was not significant.

Among the subgroups based on IQ, the higher triads generally obtained higher grades in science. Among the subgroups based on sex, an interesting inversion of pattern is noted. Girls in both experimental groups (345 and A) had higher science grades than did the boys in the corresponding groups. In contrast, boys in the control groups (012 and B) had higher science grades than did the girls in the corresponding groups. Neither of these patterns was tested for statistical significance.

Table XVIII summarizes similar data to those in Table XVII except that only those grades for the biological and physical sciences were used in computing the mean scores. Essentially the same patterns seem to be present in these data as were evident in the data for grades in all science courses. That is, the experimental group obtained higher grades than did the control group when the 345 group is compared to

TABLE XVI - Responses to Miscellaneous Questions Related to College Preparation in Science by Experimental and Control Groups

(Long Questionnaire Items 30 and 31)

	Group	n	Mean	Diff.	Under H_0; p*	Under H_0; p**
Item 30. How did the difficulty of your first science course in college compare to the difficulty you had expected? (1 = much less difficult, 7 = much more difficult)	345-All	85	3.72			
	012-All	78	3.96	-0.24	0.12	
	A-All	37	3.51			
	B-All	37	3.62	-0.11		0.92
Item 31. How did your actual level of interest in your first college science class compare to the interest you had expected? (1 = much less, 7 = much greater)	345-All	85	4.11			
	012-All	77	4.52	-0.41	0.10	
	A-All	37	4.11			
	B-All	37	4.11	0		

* Mann-Whitney U test

** Wilcoxon Matched-Pairs Signed-Ranks test

TABLE XVII - Mean Grades in All First-Year College Science Courses by Experimental and Control Groups

Group	n	Mean	Diff.	Under H_o, p*	Group	n	Mean	Diff.	Under H_o, p**
345-All	73	2.22	+ 0.30	0.13	A-All	29	2.29	-0.17	0.33
012-All	62	1.92			B-All	29	2.46		
345-Boys	38	2.16	+ 0.24	0.47	A-Boys	11	1.99	-0.92	< 0.01
012-Boys	31	1.92			B-Boys	11	2.91		
345-Girls	35	2.29	+ 0.37	0.08	A-Girls	18	2.48	+ 0.30	> 0.05
012-Girls	31	1.92			B-Girls	18	2.18		
345-Top Third	27	2.56	+ 0.26	0.35	A-Top Third	12	2.58	-0.48	$0.05 > p > 0.02$
012-Top Third	24	2.30			B-Top Third	12	3.06		
345-Middle Third	24	2.12	+ 0.09	0.73	A-Middle Third	9	2.17	+ 0.28	> 0.05
012-Middle Third	15	2.03			B-Middle Third	9	1.89		
345-Bottom Third	22	1.92	+ 0.47	0.10	A-Bottom Third	8	2.00	-0.19	> 0.05
012-Bottom Third	23	1.45			B-Bottom Third	8	2.19		

* Mann-Whitney U test

** Wilcoxon Matched-Pairs Signed-Ranks test

TABLE XVIII - Mean Grades in First-Year College Biological and Physical Science Courses by Experimental and Control Groups

Group	n	Mean	Diff.	Under H_0; p*	Group	n	Mean	Diff.	Under H_0; p**
345-All	57	2.32			A-All	16	2.13		
012-All	53	1.95	+ 0.37	0.055	B-All	16	2.65	-0.52	> 0.05
345-Boys	34	2.20			A-Boys	9	1.88		
012-Boys	28	1.86	+ 0.34	0.30	B-Boys	9	2.89	-1.01	$0.01 < p < 0.02$
345-Girls	23	2.51			A-Girls	7	2.64		
012-Girls	25	2.02	+ 0.49	0.05	B-Girls	7	2.34	+ 0.30	$> 0.11^{+}$
345-Top Third	24	2.73			A-Top Third	8	2.55		
012-Top Third	23	2.21	+ 0.52	0.09	B-Top Third	8	3.19	-0.64	> 0.05
345-Middle Third	17	2.21			A-Middle Third	5	2.10		
012-Middle Third	12	1.98	+ 0.23	0.37	B-Middle Third	5	2.18	-0.08	$> 0.13^{+}$
345-Bottom Third	16	1.83			A-Bottom Third	3	1.50		
012-Bottom Third	18	1.55	+ 0.28	0.37	B-Bottom Third	3	2.00	-0.50	

* Mann-Whitney U test

** Wilcoxon Matched-Pairs Signed-Ranks test

+ Walsh test (used because n was to small for Wilcoxon test) the 012 group. The control group obtained higher grades than did the experimental group when the A group is compared to the B group. However, few of the differences are significant at the arbitrary 0.05 level of significance.

The only significant differences for grades in the physical and biological sciences are those between girls in the 345 and 012 groups and that between boys in the A and B groups.

Among the subgroups based on IQ, the higher triads generally obtained the higher grades.

Factors Affecting Interpretation of "Grade" Data

Interpretation of patterns in the data regarding first-year college science grades must take into account an important fact--the University School did not give grades to its students. This means that graduates of the University School entered college without having had experience in the practical problems entailed in competing for grades. This may well invalidate any comparison of first-year college science grades for groups A and B.

Another possible reason for invalidating the comparison of the first-year college science grades for the A and B groups can be found in Table XIX. This table summarizes the selectivity indexes of the colleges entered by individuals in the test groups. It is apparent that group A tended to enter more selective colleges. From this it can be inferred that students in group A would be in "stiffer" competition for grades.

In view of the factors cited above, comparison of first-year college science grades for groups A and B should probably be discounted. Comparison of grades for the 345 and 012 groups, however, should not be considered valid.

Thus, the overall impression produced by data on grades in first-year college science is that of a distinct favorability for the experimental groups.

TABLE XIX - Selectivity of Colleges Entered by Individuals in Experimental and Control Groups

(N = non-selective; S = selective; VS = very selective; HS = highly selective; MS = most selective*)

Group	No. of Individuals in Category N(1)	S(2)	VS(3)	HS(4)	MS(5)	Total	Mean Selectivity
345	55	10	12	7	10	94	2.01
012	56	4	12	8	11	91	2.05
			$\chi^2 = 2.68$ df = 4 Under H_0; $0.50 < p < 0.70$				
A	31	5	9	4	7	56	2.13
B	37	3	13	2	1	56	1.70
			Under H_0; $p = 0.07$ (Wilcoxon matched-pairs signed-ranks test)				

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* Selectivity ratings from Cass, James, and Birnbaum, Max, Comparative Guide to American Colleges, New York, Harper & Row, 1965. See Appendix G for selectivity ratings of specific colleges attended by experimental and control groups.

IV - CONCLUSIONS AND RECOMMENDATIONS

The most important conclusion gained from this investigation is that a unified science curriculum is a viable alternative to the traditional science curriculum structure in the high school.

Graduates from a secondary school unified science program have attained greater interest in science and greater scientific literacy than have comparable graduates from conventional science programs. These gains have not been achieved at the expense of less effective preparation for college science. This study has demonstrated that graduates from the unified science program performed at least as well in first-year college science courses as did their counterparts who graduated from a conventional science program.

In summary, a unified science curriculum has enhanced the achievement of many long-range goals of science education without sacrificing achievement in preparation for college.

Many high school science teachers have avoided initiating curricular innovations because of their undue concern that a relatively small percentage of their graduates be prepared adequately for college science courses. By adhering to traditional courses, these reluctant teachers have achieved a false measure of security and have contributed to the tremendous inertia resisting change that has come to typify much of American education. The results of this investigation may well contribute to a diminution of this inertia.

This investigation and its results may well establish a point of departure from tradition by having made a tentative step in the direction of actual evaluation of achievement of long-range goals of science education as a function of curriculum structure. The methodology used in the construction of the Abridged Scientific Literacy Instrument can be developed further to provide a viable alternative to end-of-course tests as the measure of curriculum evaluation.

The Abridged Scientific Literacy Instrument has given an operational aspect to the testing of certain goals of science education that, traditionally, have been developed no further than the talking stage. The instrument itself may well be worthy of refinement, modification, and extension.

Other efforts to develop unified science curriculums should gain momentum from the findings of this investigation. While educational faddism, as such, is to be deplored, the barriers to try something different in curriculum structure should be lowered now that the trail has been broken.

Unified science education, as it has been practiced, must certainly continue to evolve. Its nature is such that a diversity of specific course structures can, and should, be devised under its banner. The viability of unified science curriculums raises more questions than it answers and, hopefully, increasing numbers of science educators and students will become involved in the development of unified science programs.

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APPENDIX A

DEVELOPMENT OF THE ABRIDGED SCIENTIFIC LITERACY INSTRUMENT (ASLI)

Scientific literacy is a frequently used term and most science educators agree, in a general way, on the various dimensions of scientific literacy. To devise a test for all the aspects of scientific literacy was deemed to be beyond the scope of this investigation. No other appropriate test was available since a large proportion of the test populations had experienced previously those commercially produced instruments that otherwise might be feasible.

The Abridged Scientific Literacy Instrument (ASLI) used to obtain part of the data used in this research was developed by the procedures described in succeeding paragraphs.

General Objectives of Science Educators

In terminology of science education, achievement of the "general objectives of science instruction" is synonomous with achievement of "scientific literacy."

Haney identified six "general objectives of science instruction ... to provide a basis for evaluating curriculum projects."* These six objectives were assumed to be valid as a starting point for development of the ASLI.

Three of the six general objectives were taken as the basis for constructing the ASLI. These were:

1. "The pupil should acquire the attitudes of scientists and learn to apply these attitudes appropriately in his daily experience."
2. "The pupil should come to understand the various interrelationships between science and society."
3. "The pupil should acquire a variety of interests that may lead to hobbies and possibly to a vocation."

The three general objectives that were omitted were deemed to be impractical for this research because of limitations (mainly time) imposed by the fact that the test populations were scattered geographically and all data-gathering processes would have to be entered into more or less voluntarily by the individuals involved. The omitted objectives (using Haney's numerical designations) were:

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* Haney, Richard, The Changing Curriculum: Science, Washington Association for Supervision and Curriculum Development, 1966.

> "1. The pupil should acquire knowledge which he can use to explain, predict and control natural phenomena.
>
> 2. The pupil should grow in his ability to engage in the processes of science and to apply these processes in appropriate situations as he confronts them in daily life.
>
> 5. The pupil should learn numerous useful manipulative skills through the study of science."

Development of Items for the Abridged Scientific Literacy Instrument (ASLI)

Through the months of March, April, and May the principal investigator constructed a large number of multiple-choice (later dropped) and seven-point-scale items. The responses to these items hopefully would reflect attainment (or non-attainment) of the selected objectives. Each of the items was based on a topic of current scientific interest. Special emphasis was placed on selecting topics with which some controversy was associated. Publications such as *Science*, *Bulletin of the Atomic Scientists*, *Impact*, *Science Digest*, and *Popular Science* served as sources of potential topics.

Items in the seven-point format consisted of situation-establishing statements followed by the seven-point-scale of which only the extreme points and the mid-point were explicated as possible responses. The scale represented a continuum along which the future respondent would be directed to mark his personal "position."

At the time of writing the items there was no consideration given to what "right" response would be expected.

First Refinement of Items

The principal investigator reviewed the collection of items with several teaching colleagues. Revisions were made on the basis of suggestions. Each of the reviewers had previously manifested a great interest in general education in science.

Second Refinement of Items

All items were administered to the seniors of The Ohio State University High School. One class period (55 minutes) was used to enable students to respond to the items. They were asked to make marginal notes if such seemed appropriate.

The following day, one class period was devoted to discussion of the items. As a result of the written responses and the discussion, many modifications were made. The principal change was to drop the multiple-choice format. This decision was based on the general feeling that too frequently none of the five choices provided was an adequate decision of the individual's position in relation to the situation and question established.

The students expressed a strong preference for the seven-point-scale format provided that the extremes really represented extreme points of view.

Other modifications resulted from student comments such as "That really asks two questions," "The question is vague," "It would be more interesting if ...," "How about...?", etc.

Item Selection Panel

A potential panel of science educators was selected from the membership roster of the National Association for Research in Science Teaching (NARST). A table of random numbers was used to select the potential panel after individuals professionally associated with commercial endeavors were struck from the list. NARST members with overseas addresses were excluded also.

One hundred four potential panel memners were obtained. Each was sent a package consisting of one copy of ASLI Form I for evaluation in terms of specific objectives, direction sheets, a stamped return envelope, and an appropriate cover letter. (See the last four pages of this Appendix for replicas of representative pages.) The ASLI Form I was composed of fifty-four individual items.

Each member of the panel was asked to evaluate each item as to how well he felt its response would reflect attainment of a certain general objective. Panelists were given the option of rating each item on a five-point scale. Specific points on the scale in order of increasing efficacy were unsatisfactory, satisfactory, adequate, good, excellent.

In addition, each panelist was asked to respond to each item on the seven-point subject response scale as he would expect an "ideal" scientifically literate person to do if that person had graduated from high school during the past seven years.

It should be recalled that the original group of items deal with topics which had aroused some controversy in recent years. By responding in the manner directed, the panelists created a kind of operational definition for scientific literacy. In effect, for each item or for the whole collection of items, it could now be said that a scientifically literate person is one who responds to these items in a given way. Or, with slightly different interpretation, of two subjects that one is more scientifically literate who comes closer to the norm established by the composite responses of the panel.

Use of Panel Responses

It was arbitrarily decided that the selection panel would be composed of the first fifty respondents or of those that responded within fifteen days of the date on which materials were mailed to potential panel members. The choice between the two criteria was based on whichever occurred first. The latter actually did and, consequently, thirty-six individuals comprised the selection panel. The panel had a rather broad geographical distribution as shown in Table XX.

Because of the time element involved, it was possible to utilize an additional ten panel members in establishing the "ideal" response for each item. The composition of the panel is shown in Table XXI.

Guidelines for item selection had been established prior to the arbitrary cut-off date, and were used to eliminate specific items from the proposed ASLI. Before applying these guidelines, an "evaluation-selection score" was determined for each item. This score was determined by subtracting twice the number of "unsatisfactory" panel ratings from the sum of the "good" and "excellent" panel ratings. A mean and standard deviation were calculated for the panel's ideal response to each item.

An item was rejected from ASLI Form I if:

1. The panel ratings for it showed more than four combined "unsatisfactory" and "no response" replies.
2. The "evaluation-selection score" for it was less than eight.
3. The standard deviation of the panel's ideal answers to it was greater than 1.80.
4. The distribution of the panel's ideal answers to it on the seven-point scale was clearly bi-modal.

TABLE XX - ASLI Item Selection Panel Composition by States

Alabama	1	Michigan	4
Arizona	1	Minnesota	1
California	3	Nebraska	2
Delaware	1	New York	4
Illinois	1	Ohio	2
Indiana	4	Oregon	1
Iowa	2	Pennsylvania	1
Kansas	1	Tennessee	1
Maryland	1	Texas	3
Massachusetts	1	Wisconsin	1

Total = 36

TABLE XXI - ASLI "Ideal Responses" Panel Composition by States

Alabama	1	Minnesota	1
Arizona	1	Nebraska	3
California	4	New York	5
Delaware	1	Ohio	2
Illinois	1	Oklahoma	1
Indiana	6	Oregon	1
Iowa	2	Pennsylvania	1
Kansas	1	Tennessee	1
Louisana	1	Texas	4
Maryland	1	Virginia	1
Massachusetts	2	Wisconsin	1
Michigan	4		

Total = 46

5. The marginal comments by panelists clearly indicated that the item was seriously subject to misinterpretation and/or actually contained two separate items.

From ASLI Form I which contained fifty-four items, a total of twenty-eight items survived. The surviving items comprised ASLI Form II and make up the first five pages of the Long Questionnaire that is found in Appendix B.

Table XXII summarizes pertinent data used in selecting items for ASLI Form II. Table XXIII shows the same data for the items rejected from ASLI Form I.

TABLE XXII - Summary of Panel Responses to Items Used in the Final Form of the ASLI

ASLI Form I Number	"Ideal Answer" Panel Mean	"Ideal Answer" Panel SD	Frequency of Panel Judgements U	S	A	G	E	No Responses	Selection Guide Number	ASLI Final Form Number
2	5.6	1.09	0	2	10	18	6	0	24	7
3	4.8	1.00	1	1	11	14	8	1	20	22
5	6.5	0.97	2	4	7	7	16	0	19	4
7	4.6	1.78	0	5	11	11	8	1	19	21
8	1.4	1.18	3	1	6	13	12	1	19	12
10	6.6	1.37	2	4	7	4	18	1	16	11
14	1.9	1.66	2	4	10	12	7	1	15	3
16	3.0	1.78	1	10	13	8	3	1	9	19
20	1.9	1.64	3	6	5	9	13	0	16	16
22	5.5	1.07	3	3	3	17	9	1	20	15
24	4.9	1.64	3	4	5	17	6	1	17	6
27	6.1	1.02	1	4	4	11	15	1	24	17
28	3.9	1.30	2	5	8	15	5	1	16	9
29	5.8	1.45	2	6	7	10	10	1	16	13
31	1.9	1.01	3	6	6	14	6	1	14	2
33	5.2	1.55	1	2	8	17	7	1	22	5
35	6.6	0.61	0	0	2	17	16	1	33	10
36	5.3	1.51	3	2	8	11	11	1	16	8
39	2.5	1.48	1	7	8	13	5	2	16	1
40	5.5	1.22	1	0	9	14	10	2	22	18
41	2.6	0.88	1	5	13	7	8	2	13	20
45	1.8	1.12	2	4	6	12	11	1	19	14
47			3	9	10	14	0	0	8	26
48			3	6	5	13	9	0	16	25
49			4	6	8	13	5	0	10	23
51			1	3	13	16	3	0	17	24
52			2	6	8	15	5	0	16	27
53			2	6	10	14	4	0	14	28

TABLE XXIII - Summary of Panel Responses to Items Rejected from the ASLI-Form I

ASLI Form I Number	"Ideal Answers"		Frequency of Panel Judgements						Selection Guide Number
	Panel Mean	Panel SD	U	S	A	G	E	No Response	
1	1.7	0.80	6	4	8	13	5	0	6
4	3.1	1.50	7	10	5	7	7	0	0
6	4.4	1.98	8	2	4	16	6	0	6
9	4.3	2.24	2	3	5	11	14	1	21
11	4.9	1.63	4	2	6	9	13	2	14
12	3.5	2.12	4	9	5	10	7	1	9
13	3.4	2.15	7	6	11	5	6	1	-3
15	3.0	1.78	4	6	6	15	4	1	11
17	2.6	1.97	2	6	7	12	8	1	16
18	4.5	1.75	1	5	10	10	10	0	18
19	3.4	2.22	4	8	7	8	9	0	9
21	5.0	1.70	8	8	6	6	8	0	-2
23	6.6	0.90	6	6	5	11	7	1	6
25	3.9	1.83	3	5	9	15	2	2	11
26	3.7	1.22	6	5	9	8	7	1	3
30	4.7	1.69	7	5	8	10	5	1	1
32	2.6	1.94	3	3	9	10	10	1	14
34	3.5	1.79	2	3	12	11	7	1	14
37	5.2	1.53	3	6	7	9	10	1	13
38	2.6	1.66	3	8	5	11	7	2	12
42	1.9	1.01	4	8	3	12	7	2	11
43	4.2	1.65	5	6	8	9	7	1	6
44	4.3	2.23	11	3	6	8	5	3	-9
46			6	6	10	12	2	0	2
50			5	4	9	12	5	1	7
54			2	4	7	13	7	2	10

Directions for Review of
Questions by Science Educators

Phase I

Read each question. Judge how well you think its answer reflects attainment (or non-attainment) of the general objective of science education that is stated at the top of each page.

Indicate your evaluation of each question by circling the symbol that comes closest to your judgement. The symbols and their meanings to be used throughout are as follows:

U = unsatisfactory. The item does not reflect attainment of the objective. It should not be used.

S = satisfactory-min. The item may reflect some degree of attainment of the objective but is of minimum value.

A = adequate. The item probably reflects attainment of the objective.

G = good. The item reflects attainment of the objective.

E = excellent. The item undoubtedly reflects attainment of the objective and does so incisively.

A table of symbols and abbreviated meanings appears at the upper right of each page.

NOTE: The "general objective" may differ from one page to the next. A colored page precedes a shift to a new objective.

Phase II

Re-read each question. Answer each question according to the general directions on the next page. Answer each as you would expect a scientifically literate person to do if that person had graduated from high school during the past seven years.

Phase III

Return mimeographed material in the stamped and addressed envelope that is provided.

GENERAL OBJECTIVE: The pupil should come to understand the various interrelationships between science and society.

JUDGEMENT

U=unsatisfactory
S=satisfactory-mini
A=adequate
G=good
E=excellent

5. Several years ago a product called "AD-X2" was produced and sold by a private company as an additive to automobile batteries. Numerous purchasers of this product swore (in legal testimony) that use of the product made their batteries peppier and longer lasting. The National Bureau of Standards conducted tests on AD-X2 in their laboratories and reported that it was worthless.

After the report of the tests, it was suggested that the federal government should prohibit the company from claiming that AD-X2 was beneficial when used in automobile batteries. What are your feelings about this suggestion?

disagree strongly — neutral — agree strongly

☐ ☐ ☐ ☐ ☐ ☐ ☐

U S A G E

6. Frequently industrial scientists change jobs in order to obtain better pay or improved working conditions. When this happens, the scientist's new employer is often a competitor of the old employer. Do you think that the scientist should feel free to reveal to his new employer that knowledge which he gained while working for his old employer?

absolutely not — neutral — absolutely yes

☐ ☐ ☐ ☐ ☐ ☐ ☐

U S A G E

7. What is your reaction to the following statement? "If current trends are continued, it is very likely that most scientific activity in the future will be financed by state or government agencies."

disagree strongly — neutral — agree strongly

☐ ☐ ☐ ☐ ☐ ☐ ☐

U S A G E

GENERAL OBJECTIVE: The pupil should acquire the attitudes of scientists and learn to apply these attitudes appropriately in his daily experience.

JUDGEMENT

U=unsatisfactory
S=satisfactory-min
A=adequate
G=good
E=excellent

22. In judging the merit of a scientist's findings, do you feel that a scientist's professional reputation or his techniques of investigation should be more important in judging whether or not his findings should be accepted?

reputation alone — both equally — techniques alone

☐ ☐ ☐ ☐ ☐ ☐ ☐

U S A G E

23. Do you think that Russian scientists and technologists would ever have been able to develop a nuclear bomb if they had not received information from spies concerning the nuclear bomb that was developed in the United States?

definitely no — neutral — definitely yes

☐ ☐ ☐ ☐ ☐ ☐ ☐

U S A G E

24. The theory of evolution provides an explanation of how man originated on Earth by developing from some other living organism. Many arguments have been conducted on the amount of certainty that should be assigned to the theory of evolution on the basis of actual evidence.

How certain are you that the present theory of evolution accounts for the origin of man on Earth?

extremely uncertain — probably certain — absolutely certain

☐ ☐ ☐ ☐ ☐ ☐ ☐

U S A G E

25. It has been said that manned space flight is an unnecessarily expensive way to explore space since instruments alone could gain the same information at a much lower cost. How do you feel about this statement?

disagree strongly — neutral — agree strongly

☐ ☐ ☐ ☐ ☐ ☐ ☐

U S A G E

GENERAL OBJECTIVE: The pupil should acquire a variety of interests that may lead to hobbies and possibly a vocation.

JUDGEMENT

U=unsatisfactory
S=satisfactory
A=adequate
G=good
E=excellent

46. If you have sufficient time, how will the number of science related articles and books that you will read in the coming year compare to the number you read during the past year?

much less | the same | much greater

☐ ☐ ☐ ☐ ☐ ☐ ☐

U S A G E

47. During the past year, how has the number of science related articles and books you have read seem to compare to the number read by people that you know?

mine seems much less | the same | mine seems much more

☐ ☐ ☐ ☐ ☐ ☐ ☐

U S A G E

48. How has your interest in science changed since you left high school?

great decrease | no change | great increase

☐ ☐ ☐ ☐ ☐ ☐ ☐

U S A G E

49. How does your current interest in science seem to compare to that of people you know?

mine seems much lower | the same | mine seems much higher

☐ ☐ ☐ ☐ ☐ ☐ ☐

U S A G E

50. How does your current knowledge of science seem to compare to that of people you know?

mine seems much lower | the same | mine seems much greater

☐ ☐ ☐ ☐ ☐ ☐ ☐

U S A G E

APPENDIX B

QUESTIONNAIRE REPLICAS

The first page of this appendix is the "Short Questionnaire." With a cover letter and a stamped return envelope it was the initial contact with each subject.

Item 7 of the short questionnaire was clipped from each affirmative response and was sent to the appropriate institution with a request for the individual's transcript.

The remainder of the appendix is the "Long Questionnaire." With a cover letter and a stamped return envelope it was the second contact with each subject.

Pages 1-4 of the long questionnaire comprise the Abridged Scientific Literacy Instrument (ASLI).

Page 5 of the long questionnaire contains "interest" items while page 6 contains "college preparation" items. The latter was sent only to those subjects who indicated in their response to the short questionnaire that they had entered college immediately after high school.

STUDY OF SELECTED HIGH SCHOOL GRADUATES

(Ohio State University Research Foundation Project # 2451)

1. Did you enroll in an educational program of some type in the year immediately after graduation from high school?

(Circle one) Yes No

IF YOU ANSWERED "NO" TO QUESTION 1, PLEASE RESPOND TO ITEMS 2, 3, AND 4 ONLY.

2. For whom (company or individual) did you work in the year following graduation from high school?____________________

____

____

3. Have you enrolled in some type of educational program later than the year immediately following graduation from high school?

(Circle one) Yes No

If so, when did you enroll?____________ Where?__________

____

4. What is your present occupation? ____________________

IF YOU ANSWERED "YES" TO QUESTION 1, PLEASE RESPOND TO ITEMS 5, 6, AND 7 ONLY.

5. What educational institution did you attend in the year after graduation?

____________________ ____________________
(Name) (Location)

6. What degree, diploma or certificate did you intend to work toward when you first enrolled? ____________________
If you entered a college, in what area did you plan to major when you first entered? ____________________

7. Will you permit this research project to obtain a transcript of your educational record since graduation, provided that it is treated with absolute confidence? __________

Date ________________ Signed ____________________

General Directions for Answering Questions

Each question calls for an answer based on your personal opinion. Each question has possible answers that range from one extreme to another. A series of seven blocks spanning the range of possible answers is provided. Mark the block that corresponds most closely to your answer.

The following example shows how the answer form can be used.

0. How do you feel about a proposal that Ohio should enact a law to establish a state personal income tax?

disagree strongly			neutral			agree strongly
☐	☐	☐	☐	☐	☐	☐

In answering this question, an individual who agrees strongly with the income tax proposal would check the box on the far right.

In another case, the person answering the question may feel some degree of agreement or disagreement, but not to the extent of the extremes described. One of the unlabeled boxes would be checked.

If the person answering the question lives in California, he may feel no personal involvement in the proposed tax. In this case the box labeled "neutral" would be checked.

1. Many people claim that unidentified flying objects (UFO's) are real. By "real" they usually mean that the UFO's are produced and directed by an intelligence that is located somewhere other than the Earth.

What are your feelings about the reality of UFO's as it (reality) is described above?

disagree strongly			neutral			agree strongly
☐	☐	☐	☐	☐	☐	☐

2. Foxes are natural predators of rabbits and quail. As such, foxes annually kill a large number of these small animals. A hunting club in southeast Ohio has proposed that a concentrated effort be made to eliminate the fox from a two-county area so that rabbit and quail hunting will be better.

How do you feel about this proposal?

oppose strongly			neutral			support strongly
☐	☐	☐	☐	☐	☐	☐

3. Do you feel that state laws should be passed that would force all schools within the state to teach certain scientific theories such as those of evolution and atomic structure?

absolutely no			neutral			absolutely yes
☐	☐	☐	☐	☐	☐	☐

4. Several years ago a product called "AD-X2" was produced and sold by a private company as an additive to automobile batteries. Numerous purchasers of this product swore (in legal testimony) that use of the product made their batteries peppier and longer lasting. The National Bureau of Standards conducted tests on AD-X2 in its laboratories and reported that it was worthless.

After the report of the tests, it was suggested that the federal government should prohibit the company from claiming that AD-X2 was beneficial when used in automobile batteries. What are your feelings about this suggestion?

disagree strongly			neutral			agree strongly
☐	☐	☐	☐	☐	☐	☐

5. It has been said that a large proportion of scientific research sponsored by industry or government agencies should not be intended to produce results that will have immediate or even foreseeable practical applications. How do you feel about this statement?

disagree strongly			neutral			agree strongly
☐	☐	☐	☐	☐	☐	☐

6. The theory of evolution provides an explanation of how man originated on Earth by developing from some other living organism. Many arguments have been conducted on the amount of certainty that should be assigned to the theory of evolution on the basis of actual evidence.

How certain are you that the present theory of evolution accounts for the origin of man on Earth?

extremely uncertain			probably certain			absolutely certain
☐	☐	☐	☐	☐	☐	☐

7. Scientists often conduct research or development projects that result in the creation of products that can have a direct effect on the general public. How much responsibility do you feel that the scientist has to make sure that such products are used in the best interests of mankind?

much less than the average citizen			the same as the average citizen			much more than the average citizen
☐	☐	☐	☐	☐	☐	☐

8. What amount of eventual damage to his health do you think is risked by a person in his early twenties who regularly smokes one pack of cigarettes per day?

none			moderate			great
☐	☐	☐	☐	☐	☐	☐

9. For many years people have wondered whether or not there is life on the planet Mars. What do you think is the best present day answer to the question, "Is there life (in some form) on the planet Mars?"

definitely no			undecided			definitely yes
☐	☐	☐	☐	☐	☐	☐

10. How do you feel about the notion that a good scientist is one that is willing to change his ideas and beliefs when confronted by new evidence?

disagree strongly			neutral			agree strongly
☐	☐	☐	☐	☐	☐	☐

11. How do you feel about the notion that the theory of evolution should be taught in all high schools in this nation?

strongly disagree — neutral — strongly agree

☐ ☐ ☐ ☐ ☐ ☐ ☐

12. Some people have said that the world would really be a better place in which to live today if only science had not been allowed to get involved in so many different aspects of men's lives. How do you feel about this point of view?

strongly disagree — neutral — strongly agree

☐ ☐ ☐ ☐ ☐ ☐ ☐

13. Do you feel that it would be proper for scientists to conduct research designed to discover biochemical and psychological differences that may exist between Negroes and Whites?

absolutely no — neutral — absolutely yes

☐ ☐ ☐ ☐ ☐ ☐ ☐

14. A recent report described a test of a new headache remedy called "Sertanil." The test was conducted by an independent testing laboratory.

In the test 100 people, who said they were suffering from a headache, were given one "Sertanil" tablet with a glass of water. Ten minutes later, 85 of the people said that their headaches were gone.

On the basis of the test reported, how confident are you that "Sertanil" is an effective headache remedy?

no confidence — 50% confidence — absolute confidence

☐ ☐ ☐ ☐ ☐ ☐ ☐

15. In judging the merit of a scientist's findings, do you feel that a scientist's professional reputation or his techniques of investigation should be more important in judging whether or not his findings should be accepted?

reputation alone — both equally — techniques alone

☐ ☐ ☐ ☐ ☐ ☐ ☐

16. How much conflict has there been between religion and science in your own thinking during the past year?

no conflict — moderate conflict — great conflict

☐ ☐ ☐ ☐ ☐ ☐ ☐

17. The addition of small amounts of fluoride compounds to city water supplies (fluoridation) is intended to reduce tooth decay among the population of the city. Some people, however, have opposed fluoridation for various reasons.

Do you feel that city water supplies should be fluoridated?

absolutely no			neutral			absolutely yes
☐	☐	☐	☐	☐	☐	☐

18. What do you feel is the best answer to the question, "Is there intelligent life somewhere in the universe other than on the Earth?"

certainly no			uncertain			certainly yes
☐	☐	☐	☐	☐	☐	☐

19. How do you feel about the idea that this nation's scientists are largely responsible for whatever favorable opinions other nations have for our nation?

disagree strongly			neutral			agree strongly
☐	☐	☐	☐	☐	☐	☐

20. What is your feeling regarding the relative benefit or danger to one's health resulting from acquiring a deep suntan?

great danger			neither benefit nor danger			great benefit
☐	☐	☐	☐	☐	☐	☐

21. What is your reaction to the following statement? "If current trends are continued, it is very likely that most scientific activity in the future will be financed by state or government agencies."

disagree strongly			neutral			agree strongly
☐	☐	☐	☐	☐	☐	☐

22. Assume that the general public should know what scientists are currently working on and what their recent discoveries have been. Who do you feel should take the initiative in collecting and distributing such information, non-scientists or scientists?

non-scientists completely			both equally			scientists completely
☐	☐	☐	☐	☐	☐	☐

23. How does your current interest in science seem to compare to that of people you know?

mine seems much lower — the same — mine seems much higher

☐ ☐ ☐ ☐ ☐ ☐ ☐

24. What proportion of your hobbies and spare time activities do you feel are science related?

none — half — all

☐ ☐ ☐ ☐ ☐ ☐ ☐

25. How has your interest in science changed since you left high school?

great decrease — no change — great increase

☐ ☐ ☐ ☐ ☐ ☐ ☐

26. During the past year, how has the number of science related articles and books you have read seem to compare to the number read by people that you know?

mine seems much less — the same — mine seems much more

☐ ☐ ☐ ☐ ☐ ☐ ☐

27. What proportion of the books that you have read of your own choosing in the past two years has been devoted to scientific topics?

none — half — all

☐ ☐ ☐ ☐ ☐ ☐ ☐

28. Other than from books, do you feel that the knowledge you have gained about science during the past year has come mainly from reading popular publications (e.g. newspapers and Time magazine) or from technical publications (e.g. The American Journal of Botany)?

completely popular — both equally — completely technical

☐ ☐ ☐ ☐ ☐ ☐ ☐

29. When you first entered college, how did your general interest in science seem to compare to that of other freshmen?

much less | the same | much greater

☐ ☐ ☐ ☐ ☐ ☐ ☐

30. How did the actual difficulty of your first science course in college compare to the difficulty you had expected?

much less difficult | the same as expected | much more difficult

☐ ☐ ☐ ☐ ☐ ☐ ☐

31. How did your actual level of interest in your first college science course compare to the interest you had expected?

much less | the same as expected | much greater

☐ ☐ ☐ ☐ ☐ ☐ ☐

32. When compared to other students in your first college science course, how well do you feel you were prepared to understand the terminology used in the course?

very poorly | about average | very well

☐ ☐ ☐ ☐ ☐ ☐ ☐

33. When compared to other students in your first college science course, how well do you feel that you were prepared to use the laboratory?

very poorly | about average | very well

☐ ☐ ☐ ☐ ☐ ☐ ☐

34. When compared to other students in your first college science course, how well do you feel you were prepared to handle the mathematical parts of the course?

very poorly | about average | very well

☐ ☐ ☐ ☐ ☐ ☐ ☐

APPENDIX C

SCHOOL SETTINGS FOR EXPERIMENTAL AND CONTROL GROUPS

The Ohio State University School

The Ohio State University School was the setting for the science instructional program that was provided for the experimental 345 sample and the control 012 sample. During the nine years that these groups were in grades 9-12 there were few major changes in other areas of the curriculum even though the function of the school was that of demonstration and innovation. The school did not function as a practice teaching laboratory.

During the nine-year period there were some classroom innovations in English. A generative grammar approach was tried as an innovation in teaching expository and literary writing.

The formal mathematics program was unchanged in overall structure. The social studies program was based mainly on a core approach although many of the same units were selected for study by the classes of 1960-65.

For many years it had been school policy to permit capable students to audit certain college courses in place of a high school course. Mathematics and foreign language areas were most often selected. In the nine-year period under discussion, only two students elected to take a college course in science.

All instructional periods were 55-minutes long. There were no special laboratory periods. There were no study halls and all students were scheduled for all seven periods. Physical education was a daily class for all students. All science classes met five days per week and the school year was approximately 165 days long. The latter figure is about 15-days short of the recommended and usual minimum in Ohio. However, the University School calendar was regulated by, and in phase with, The Ohio State University calendar.

Instructional facilities of the school were antiquated by standards achieved in most public high schools. The school was planned and constructed in the early 1930's and had changed little in the intervening years. Laboratory equipment was minimal. The school library, however, far exceeded the minimum recommendations of the American Library Association; more than one thousand science books were cataloged. In addition, the library maintained a collection of science textbooks in multiple copies.

The teaching faculty of the University School were accorded ranks from instructor to associate professor in the College of Education. A typical teaching load was fifteen clock hours per week. A masters degree was considered prerequisite to acquiring a position on the staff.

Grades, as such, were not assigned to students as a matter of long-standing policy. In lieu of grades, tri-annual evaluating letters were sent to parents. At the termination of a given year's course work, a student was awarded one credit, one-half credit, or no credit for his work in each subject area. A student's transcript was merely a record of credits earned in each subject area. Students were encouraged to participate in tests of general educational development and scores from these became part of the individual's permanent record.

The University School provided instruction in grades 9-12. Approximately 400 students were enrolled at any one time. Many students attended the school for all thirteen years of schooling. Similar evaluation policies were in effect throughout the school. The atmosphere of the school, through all grades, can best be described as permissive in comparison to most Ohio schools.

The science staff, throughout the nine-year period of high school instruction that affected the groups in question, did not change radically. Table XXIV lists instructors' names for each grade level for each of the graduating classes involved in the study as an indicator of stability.

The introduction of the unified science curriculum into the University School was gradual. Thus in 1959-60, Unified Science I was instituded for all ninth graders and replaced general science as a possible credit to be earned. In 1960-61, Unified Science II was required of all sophomores and replaced biology as a possible credit. In 1962-62, Unified Science III was elective for juniors and replaced chemistry. In 1962-63, Unified Science IV was elective for seniors who had elected Unified Science III, and replaced physics.

The student population of the University School was subjectively "balanced" by selective admission policies. Ten to fifteen per cent of each class was Negro and there was a 50-50 division between the sexes. The IQ range was normal, though the mean was high. To maintain the desired balance, one-third to one-half of the students attended the school tuition free. The remainder paid regular university tuition which at the time of this study was about $140 per school year.

Worthington High School

Selected features on which Worthington High School can be compared to the University High School are presented in Table XXV. Locally, Worthington High School has a reputation as a good school in a more or less conventional mold so far as curriculum is concerned.

Course offerings were such that students were required to select earth science or physical science in grade 9. Biology was elective in grades 10-12 and chemistry, physics, and advanced biology were elective in grades 11-12.

TABLE XXIV - University School Science Teachers at Different Grade Levels for Graduating Classes of 1960-1965

Grade	Graduating Class of					
	1965	1964	1963	1962	1961	1960
9	Slesnick	Slesnick	Slesnick	Slesnick	Stilson Williams	Stilson Slesnick
10	Slesnick	Slesnick	Slesnick	Foust Slesnick	Williams Slesnick	Slesnick
11	Guitry Showalter	Showalter	Showalter	Showalter	Foust Showalter	Slesnick
12	Menefee	Guitry Menefee	Showalter	Showalter	Showalter	Slesnick

TABLE XXV - Significant and Comparable Features of University High School and Worthington High School*

Feature	University High School			Worthington High School		
Enrollment	Male	Female	Total	Male	Female	Total
Ninth grade	20	10	30	188	162	350
Tenth grade	18	20	38	127	126	253
Eleventh grade	19	18	37	117	106	223
Twelfth grade	14	18	32	97	83	180
Total	71	66	139	529	477	1006
Median IQ Range		115-120			115-120	
Percentage of graduates who go to college		> 90%			> 90%	
Home background		Upper middle class			Upper middle class	
Teacher-pupil ratio		10.8			21.6	
Number of school days per year		166			178½	
Length of class period		55 minutes			55 minutes	
Age of school plant		31 years			Older building--9 years Newer building--5 years	
Number of science teachers		2			6	
Number of science classes		5			26	
Average enrollment of		22				
science classes		22			25	

* Data gathered from 1961 principals' reports filed at the Ohio State Department of Education and from descriptive literature distributed and available from the administrative offices of both schools.

Reproduced by permission from Slesnick, Irwin, The Effectiveness of a Unified Science in the High School Curriculum, Unpublished Ph.D dissertation, The Ohio State University, Columbus, 1963.

APPENDIX D

SYLLABUS FOR THE UNIFIED SCIENCE CURRICULUM AT THE UNIVERSITY SCHOOL

The syllabus for four years of unified science at The University School occupies the subsequent pages of this appendix. The syllabus can only partially describe the course as it was taught since it specifies nothing about the methodology of instruction.

It should be emphasized that the methodology of instruction in University School science classes did not change with the advent of the unified science curriculum. For many years science classes had been student-centered; that is, students and instructors cooperatively planned many class activities. Classroom observers had found that teacher talk and student talk have about been equally divided in the usual class session. Approximately one-fourth of all class time was spent in laboratory activity.

Science classes were never textbook-oriented. Reference materials for unified science instruction, as well as for the earlier classes organized around traditional subjects, were obtained from a multiplicity of sources. The school library maintained a textbook collection to which students had free access. The science area provided a specialized library from which students could easily borrow books. Some monographs and short paperbacks were provided in classroom quantities.*

Laboratory activities were open-ended and prefaced with a bare minimum of instruction. Tests were regarded as learning situations. Most test items required that the student apply knowledge of principles, concepts, etc. to unique situations. One three-weeks block of time from each school year was devoted to conducting an individual investigation. Each student wrote a proposal for an original investigation of his own. Following teacher approval of the proposal, actual data gathering, analysis, and reporting concluded the investigation.

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* A representative collection of instructional materials including reading resources can be found in: Showalter, Victor, Unified Science Education at the Ohio State University School, Columbus: The University School, 1967 (mineographed).

Unified Science I

ORDERLINESS OF NATURE

- I. Matter, energy and life identified as contents and concerns of science
  - A. Properties of matter
    - 1. General
    - 2. Specific
  - B. Properties of energy
    - 1. General
    - 2. Specific
  - C. Properties of life
    - 1. General
    - 2. Specific
  - D. Names and symbols
  - E. Classification
    - 1. Distinguishing characteristics and grouping
    - 2. Model Scheme
- II. Order in matter
  - A. Forms of ordinary matter
    - 1. Solid, liquid, gas
    - 2. Organic-inorganic
    - 3. Mixtures and pure substances
    - 4. Pure substances--compounds and elements
    - 5. Elements as species of matter
  - B. Significant characteristics of elements (Bohr model)
  - C. Periodicity
  - D. Natural beauty of periodic table
- III Order in energy
  - A. Radiant energy
    - 1. Waves, $\lambda = v/f$
    - 2. Electromagnetic radiation distinguished
  - B. Bands of electromagnetic radiation
    - 1. Radio
    - 2. Infra-red
    - 3. Visible
    - 4. Ultra-violet
  - C. Generation and detection
  - D. Development of spectrum
- IV. Order among animals
  - A. Established Classification scheme
    - 1. Phyla . . . species
    - 2. Survey of phyla
    - 3. Ordering phyla toward increasing complexity
  - B. Reflection of evolution in ordered scheme
    - 1. Comparative anatomy
    - 2. Embryology
    - 3. Paleontology
- V. Equivalence of matter and energy

THE SUN

I. Dimensions of the sun
    A. Volume, mass and density
    B. Temperatures
    C. Position in universe
    D. Motions
    E. Compared with other stars
II. Surface characteristics
    A. Surface layers
    B. Sun spots
        1. Prominences
        2. Magnetic storms
            a. Auroras
            b. Cyclic occurrence
        3. Rotation of sun
III. Composition of sun
    A. Spectroscopy
        1. Instruments
        2. Types of spectra
        3. Qualitative analysis
    B. Interpretation of solar spectra
    C. Doppler effect
IV. Star as a thermonuclear reactor
    A. Fusion reactions
    B. Fission reactions
    C. Prout hypothesis
    D. Packing fraction curve
V. Life histories of planets, stars and universe
VI. Star as fountainhead of energy

EFFECTS OF THE SUN ON EARTH PROCESSES

Part I. Meterology

I. Atmosphere
    A. Composition
    B. Vertical structure
    C. Humidity
    D. Pressure
    E. Heat
II. Radiant energy, atmosphere and earth interaction
    A. Reflection, transmission, absorption
    B. Greenhouse effect
III. Dynamics of earth's atmosphere
    A. Wind and general circulation
    B. Air masses
    C. Weather fronts and storm structure
    D. Precipitation
    E. Weather mapping
IV. Synoptic meterology
V. Climatology
VI. Weather and geological change

Part II. Photosynthesis

- I. Plant anatomy and function
  - A. Gross
  - B. Cellular
- II. Kinds of plants
  - A. Photosynthetic
  - B. Nonphotosynthetic
    - 1. Free living
    - 2. Symbiont
- III. Photosynthetic process
  - A. Role of radiant energy
    - 1. Intake of low energy matter
    - 2. Photolysis--electrolysis
    - 3. Catalysis
    - 4. Chlorophyll
  - B. Carbon fixation
    - 1. Biochemical synthesis--production of sugar
    - 2. Secondary synthetic reactions
- IV. Analysis of factors controlling photosynthesis
    - 1. Light
    - 2. CO_2
    - 3. Water
    - 4. Chlorophyll
    - 5. Temperature
- V. Food pyramids
- VI. Struggle for place in sun

Part III. Summary

Water cycle and carbon cycle: entropy

Unified Science II

THE ORGANISM AS AN OPEN DYNAMIC SYSTEM

I. Species study--the earthworm
    A. External-internal anatomy
    B. Phylogenetic position
    C. Ecological niche
    D. Structural and physiological adaptation for carrying out life processes.
        1. Motion
        2. Ingestion--digestion--egestion
        3. Circulation
        4. Secretion
        5. Respiration
        6. Excretion
        7. Sensitivity
        8. Reproduction
    E. Interspecific and Intraspecific relations
II. Reaction chemistry in living and nonliving systems
    A. Respiratory structures of organisms
    B. Diffusion of gases
    C. Nature of chemical reactions
        1. Chemical bond
8   2. Reaction equations
        3. Mole concept
        4. Rates of reactions
        5. Heats of reactions
    D. Oxidation reactions
        1. Non living systems
        2. Living systems
III. Role of life in the matter-energy environment

INQUIRY AND ELECTRICITY

I. Case history--*Frogs and Batteries*
    A. Static electricity
    B. Animal electricity
    C. Electrochemistry
    D. Formal study of scientific inquiry and inquirers
II. Magnetism and electricity
    A. Interrelations
    B. Utility of interrelations
III. Electrical circuitry (DC)
IV. Nerve physiology
    A. Nerve impulse
    B. Electrocardiography, E.S.P. etc.
V. Comparison of science and technology (electronics)

FACTS AND MECHANISMS OF PHYSICAL AND ORGANIC CHANGE

- I. Evidence of geological change
  - A. Structure of earth
    - 1. Concentric layers
    - 2. Rocks and minerals
    - 3. Static face of earth--mapping
  - B. Past, present and future change
  - C. Age of earth
- II. Mechanism of geological change
  - A. Weathering and erosion
    - 1. Running water
    - 2. Glacial ice
    - 3. Wind
  - B. Volcanism
  - C. Diastrophism
    - 1. Isostasy theory
    - 2. Other theories
  - D. Mountains
  - E. Plains
- III. Evidence of organic change
  - A. Historical record in rock
    - 1. Stratigraphy and time
    - 2. Fossils
    - 3. Interpretation of fossils
      - a. Geographic
      - b. Climatic
      - c. Rock dating
      - d. Reconstruction of organisms
      - e. Evolution
  - B. Additional evolutionary evidence
    - 1. Comparative anatomy and physiology
    - 2. Embryology
    - 3. Geological distribution of organisms
    - 4. Plant and animal breeding
  - C. Coincidence of organic change with physical change
- IV. Mechanism of organic change
  - A. Darwinian theory
    - 1. Strengths
    - 2. Weaknesses
  - B. Genetics
    - 1. Reproduction
    - 2. Mendelian inheritance
    - 3. Non-Mendelian inheritance
    - 4. Mutations
  - C. Modern evolution theory
  - D. Social impact of knowledge of evolution
    - 1. Religion and science
    - 2. Eugenics
- V. The permanence of change

Unified Science III

QUANTIFICATION

- I. The art of asking meaningful questions
  - A. Recognition of provocative aspects of observable phenomena
  - B. Typical approaches to finding answers
- II. What can be quantified?
- III. Fundamental quantifications
  - A. Length (space)
    - 1. Standards
    - 2. Orders of magnitude in the universe
    - 3. Exponential notation
    - 4. Techniques of measuring
    - 5. Limitations on significant numbers
  - B. Time
    - 1. Standards
    - 2. Orders of magnitude corresponding to physical and biological events
    - 3. Techniques for measuring long and short intervals and calibration
  - C. Mass
    - 1. Standards
    - 2. Orders of magnitude corresponding to physical objects
    - 3. Techniques for estimating mass by comparison with standards
- IV. Derived quantification
  - A. Techniques of measurement of linear motion
  - B. Accelerated linear motion
    - 1. Graphic representation
    - 2. Mathematical relationships among distance, time, speed, and acceleration
    - 3. Dimensional analysis
    - 4. Magnitudes of speed observed in the universe
  - C. Scaling
  - D. Mole
    - 1. Significance of chemical formulas
    - 2. Mole concept
    - 3. Avogadro's Number
    - 4. Application of mole concept
- V. Abstract quantifications
  - A. Force
    - 1. Force as cause of accelerated motion and sources from which force arises (Newton's First Law)
    - 2. Relationships between force and motion
    - 3. Quantity force (units)
    - 4. Newton's First and Second Laws
    - 5. Gravity
    - 6. Vector representation
    - 7. Projectile motion and weightlessness

B. Momentum
1. Impulse
2. Conservation
3. Newton's Third Law
C. Energy
1. Work
2. Kinetic energy
3. Conservation
D. Power
E. Forces causing rotation
1. Torque
2. Center of mass
VI. Human quantification
A. Role of quantification in studying life
B. Physiological characteristics
1. Body measurements and ratios
2. Energy dissipation
3. What is "normal"?
4. Signigicant difference
C. Psychological characteristics
1. Learning curve
2. Individual difference vs. complexity of behavior
3. Relative value of subjective data (projective drawings)
D. Psychophysics
1. Reaction time
2. Stimulus

PERCEPTION

I. Relationship between physical world and perceived world
A. Stimuli and senses
B. Effect on various evolutionary levels of life
C. Similarity of information sent to brain from various sensors
D. Optical illusions
II. Light perception
A. Sources of light
B. Biological effects of light (photodermatism, photo-orientation, photoaxis, etc.)
C. Detection
1. Physical mechanisms
2. Biological mechanisms (gross anatomy of organs)
3. Range of human perception
D. Mechanisms of signal transmission from light sensor to brain
E. Threshold intensity
F. Weber's Law
G. Theories of color vision

- III. Auditory Perception
    - A. Physical nature of sound
        - 1. Sources
        - 2. Model
        - 3. Pitch and Intensity
    - B. Detection
        - 1. Physical detectors
            - a. transducers
            - b. oscilloscope
        - 2. Resonance
        - 3. Anatomy of the ear
        - 4. Range of human perception
    - C. Threshold intensity
    - D. Weber's Law
    - E. Auditory theories
- IV. Chemical Perception
    - A. Taste
        - 1. Stimuli
        - 2. Detection
        - 3. Thresholds
        - 4. Solutions
    - B. Smell
        - 1. Stimuli
        - 2. Detection
        - 3. Thresholds
- V. Cutaneous Senses
    - A. Temperature
    - B. Pressure
- VI. Time Perception
- VII. Extrasensory Perception

MODELS

- I. Types of models
    - A. Replica
    - B. Ideal
    - C. Prototype
    - D. Scientific
- II. Models in science
    - A. Use
    - B. Method of establishing
    - C. An obsolete model (phlogiston)
- III. Developing a model for light
    - A. Particle model
    - B. Ray optics
        - 1. Reflection
        - 2. Refraction
    - C. Interference
    - D. Diffraction
    - E. Polarization
    - F. Radiometer paradox
    - G. Huygen's model

- H. Nature of wave phenomena
  - 1. Pulses
  - 2. Periodic waves
- I. Particle vs. wave model
  - 1. Wavelength for light
  - 2. Photoelectric effect
  - 3. Ether

IV. Models for matter
- A. Continuous vs. discontinuous
- B. Bohr atom
- C. Electron configuration and quantum numbers
- D. Interatomic bonds
- E. Electronegativity
- F. Hydrocarbon compounds
  - 1. Substitution reactions
  - 2. Polymerization reactions
  - 3. Isomerism
- G. Nucleus

V. Cell model

VI. Earth model
- A. Historical exemplars
- B. Concentric shell model
  - 1. Successes
  - 2. Failures

VII. Model of the Universe
- A. Big-bang model
- B. Steady state model

Unified Science IV

EQUILIBRIUM

I. Hydraulic model for dynamic equilibrium
II. Physical equilibria among solid, liquid and vapor phases
  A. Water-air system
    1. Relative humidity
    2. Vapor pressure
    3. Partial pressure
  B. Water-salt system and solubility product
  C. Bromine-water-air system
    1. Multiple equilibria
    2. temperature effects
  D. Diffusion pressure deficit (DPD)
III. Molecular equilibria
  A. NO_2-N_2O_4 system
IV. Ionic equilibria
  A. Fe^{+3}-SCN^{-1}-$FeSCN^{+2}$ system
  B. H_3O^+-OH^--H_2O system
  C. CrO_4^{-2}-$Cr_2O_7^{-2}$ system
  D. Le Chatelier's principle
  E. Ionic reactions that go to completion
  F. Acid-base reactions
V. Equilibrium within organisms (homeostasis)
VI. Equilibria among organisms
  A. Population vs. time
    1. Protists
    2. Insects
    3. Birds
    4. Mammals
  B. Populations of mixed organisms
    1. Paramecium-didinium system
    2. Paramecium-yeast system
    3. Seven species grass system
    4. Lynx-hare system
    5. Kaibab deer
  C. Population development and organism development
    1. Daphnia culture
    2. Rat colony
  D. *Homo sapiens*
VII. Static equilibrium
  A. Forces
    1. Resolution, composition, equilibrant
    2. Friction
  B. Pressures
    1. Hydrostatics
    2. Passal's principle
    3. Bernoulli's principle
    4. Archimedes principle and isostasy
    5. Atmospheric disequilibria

- VIII. Equilibria in the solar system
  - A. Solar diameter
  - B. Orbits

FIELDS

- I. Gravity
  - A. Gravity field simulator
    - 1. Properties of fields
    - 2. Orbits and properties
    - 3. Interplanetary flight and multiple gravity fields
    - 4. Applicability of model to other fields
  - B. Electric fields
    - 1. Observable properties
    - 2. Quantification
  - C. Magnetic fields
    - 1. Observable properties
    - 2. Quantification
    - 3. Interaction with electric fields
  - D. Nuclear field

FRONTIERS OF SCIENCE

- I. Current activity in various sciences
  - A. As reflected in *Scientific American*
  - B. As indicated by newspapers
  - C. As indicated by popular magazines
  - C. As indicated by technical journals
- II. Science and the citizen
  - A. Scientific literacy
  - B. Keeping up-to-date

INDIVIDUAL SCIENCE INVESTIGATION

Note: This three week unit is repeated once during each of the four years of the unified science sequence.

- I. Proposal for study
  - A. Based on question or hypothesis
  - B. Answer unknown to student
- II. Data collection and analysis
  - A. Quantitative data
  - B. Methodical collection and analysis
- III. Report of study
  - A. Description of work done
  - B. Valid generalizations
  - C. Suggestions for further study
  - D. Bibliography

APPENDIX E

REPLICAS OF MISCELLANEOUS COMMUNICATIONS USED IN THE INVESTIGATION

The atmosphere in which the investigation was conducted can be inferred from the communications replicas that comprise the body of this appendix. These, along with the materials in Appendixes A and B, represent all written communications with the panel used in developing the Abridged Scientific Literacy Instrument and with the subjects of the investigation proper. Also included are various anciliary communications.

It will be noted in the communications addressed to subjects in the test groups that the basis for the study (namely, the effects of a specific science curriculum) is not referred to as such. The study is "billed" as a "follow-up study of recent high school graduates."

In addition to the written communications, some telephone communications were made for the express purposes of:

1) urging subjects to complete and return questionnaires, and

2) interviewing several individuals to clarify their declared intent to major in mathematics when they entered college.

Each replica page is identified briefly by the bracketed caption that is in the usual location of address and salutation. The order of the replicas is that in which they were mailed.

THE OHIO STATE UNIVERSITY
School of Education
29 W. Woodruff Avenue
Columbus, Ohio 43210

(Initial contact with potential ASLI members)

Under the supervision of Professor John S. Richardson, I am conducting a study to determine what effects, if any, a unified science curriculum has had on high school graduates. The study has support from The Ohio State University and the United States Office of Education.

As a basis for one of the data sources to be used in this study, I need your reactions to the enclosed material. Your name was selected from the membership of the National Association for Research in Science Teaching. In utilizing data obtained from science educators, such as yourself, individuals will remain anonymous. Only statistical descriptions of total group responses will be reported.

Undoubtedly the demands on your time are great. However, I hope that you will be able to lend your assistance to the task at hand in the next few days.

Should you desire a report of the findings of the study, I shall be pleased to send one to you if you will complete and return the enclosed address form with your response.

Thank you in advance for your cooperation and help.

Sincerely,

Victor M. Showalter

VMS:ps

THE OHIO STATE UNIVERSITY
COLLEGE OF EDUCATION
DEPARTMENT OF UNIVERSITY SCHOOLS
29 W. WOODRUFF AVENUE
COLUMBUS, OHIO 43210

(Follow-up letter to certain ASLI panelists regarding incomplete responses)

Thank you very much for your prompt response to my recent request for help in judging the merits of certain items relating to the attainment of general objectives of science education.

Probably because of a fault in my instructions, your responses were limited to the "U S A G E" responses. Will you please mark the "boxed scale" beneath each question according to your perception of how a scientifically literate person would mark it.

Thank you again for your generous cooperation.

Sincerely,

Victor M. Showalter

VMS:ps

THE OHIO STATE UNIVERSITY
COLLEGE OF EDUCATION
DEPARTMENT OF UNIVERSITY SCHOOLS
29 W. WOODRUFF AVENUE
COLUMBUS, OHIO 43210

(General appeal for addresses - sent to parents, etc.)

Under a research grant from the United States Office of Education, I am conducting a follow-up study of selected high school graduates of 1960-1965. At the present, I am attempting to find current mailing addresses of the selected graduates so that they may receive information about the study.

Hopefully, you will be able to assist in the project by providing me with the current mailing address for   .

A stamped return envelope is enclosed for your convenience in sending me the address that is needed.

Thank you in advance for your cooperation in this worthwhile project.

Sincerely,

Victor M. Showalter
Project Director

VMS:ps

THE OHIO STATE UNIVERSITY
School of Education
29 W. Woodruff Avenue
Columbus, Ohio 43210

(Initial contact with subjects - included short questionnaire)

Your assistance is needed in a research project being conducted through The Ohio State University Research Foundation for the United States Office of Education. The research is a follow-up study of selected high school graduates of 1960-1965.

The results of the research will be of use and value to professional educators who work with high schools. This project has been endorsed by Dr. John Ramseyer, Director, School of Education of The Ohio State University. Professor John S. Richardson is the research supervisor for the project.

The high school graduates selected for the study will remain anonymous in reports of the study. The whole research staff is pledged to observe the highest ethics in respecting the individual's right to privacy.

Will you please respond to the appropriate questions on the enclosed page and return it in the envelope provided. A positive response to question seven is especially needed if you attended a college or university in the year immediately following your graduation from high school.

Thank you very much for your cooperation.

Sincerely,

Victor M. Showalter
Project Director

VMS:ps

THE OHIO STATE UNIVERSITY
School of Education
29 W. Woodruff Avenue
Columbus, Ohio 43210

(Letter to colleges requesting transcripts)

Dear Sir:

I am currently engaged in a follow-up study of high school graduates from the years 1960-1965. The project is being conducted at The Ohio State University School of Education and has been endorsed by Dr. John Ramseyer, Director of the School of Education. Professor John S. Richardson is the research supervisor for the project.

Enclosed is signed authorization for obtaining individual transcripts. The authorization blank was part of a questionnaire, and since the first part of the questionnaire is needed for our files, I have enclosed one copy of the whole questionnaire for your information.

Please send the transcript(s) for work done by the following student(s) while at your institution.

NAME	DATE OF ENTRY

The entire research staff is pledged to observe the highest ethics in respecting the individual's right to privacy and the individual graduates selected will remain anonymous in reports of this study. Thank you for your help.

Sincerely,

Victor M. Showalter
Instructor

VMS:ps

THE OHIO STATE UNIVERSITY
School of Education
29 W. Woodruff Avenue
Columbus, Ohio 43210

(First follow-up letter to subjects - including short questionnaire)

A week or so ago you received a short questionnaire that was part of a study of recent high school graduates. While the general response to the first mailing was unusually good, a response from you has not yet been received.

The potential value of this study has been recognized and endorsed by several educational leaders. However, to attain honest and accurate results from the study, data is needed from you personally. Will you please take the few seconds needed to complete the brief questionnaire and return it to me.

For your convenience, another form and return envelope are enclosed.

Thank you for your help.

Sincerely,

Victor M. Showalter

P.S. If you have mailed the first questionnaire in the past two or three days, please excuse this reminder.

VMS:ps

THE OHIO STATE UNIVERSITY
School of Education
29 W. Woodruff Avenue
Columbus, Ohio 43210

(Second contact with subjects - included long questionnaire)

Your help and cooperation in responding to the brief questionnaire that I sent to you recently is appreciated greatly. Your contribution has been and will be invaluable to the total study.

Hopefully, you will be able to invest an additional ten minutes of your time to complete the last phase of the study. Enclosed is a set of questions for you to answer. You will probably find these questions interesting as many of them deal with current topics. There are no "right" or "wrong" answers to the questions. In each, you are asked to express your opinion or point of view by simply checking a box on a seven-point scale.

As with the other information you have contributed to the study, your questionnaire responses will be strictly confidential.

It occured to me that you might be interested in receiving a summary of the results of the study in which you have been participating. I will be pleased to send you such a summary if you will complete the enclosed form and return it with the questionnaire.

Thank you again for your contribution to this research study.

Sincerely,

Victor M. Showalter

VMS:ps

THE OHIO STATE UNIVERSITY
School of Education
29 W. Woodruff Avenue
Columbus, Ohio 43210

(Second follow-up letter to subjects - included short and long questionnaires)

The follow-up study of recent high school graduates has been progressing rather well. However, there are some crucial bits of data that are missing at the present moment.

My writing to you now is a special attempt to urge you to complete and return the questionnaires that will provide the needed data.

Enclosed you will find two questionnaires. One is very brief. The second is longer. Together, they will require about twelve minutes to complete. I think you will find the second set of questions interesting since many of them deal with your opinion regarding newsworthy events. If you did not enter college in the year immediately following your graduation from high school, you can omit the last page of the long questionnaire.

Your responses to the questionnaires and the data obtained from them will be treated with utmost confidence. All data will be destroyed at the conclusion of the study. The final report of the study will cite group data only. No individual data will be reported.

It occurred to me that you might be interested in receiving a brief report of the study when it is completed. I shall be pleased to send you such a report if you will return the enclosed address form.

I do hope you will be able to return the questionnaires in the next day or so as the deadline for completing the project is approaching rapidly.

Thank you in advance for your contribution to educational research.

Sincerely,

Victor M. Showalter

VMS:ps

THE OHIO STATE UNIVERSITY
COLLEGE OF EDUCATION
DEPARTMENT OF UNIVERSITY SCHOOLS
[illegible]9 W. WOODRUFF AVENUE
COLUMBUS, OHIO 43210

August 9, 1967

(Third follow-up letter to subjects who did not grant permission to obtain transcripts)

Dear ,

In the past few weeks we have corresponded several times regarding my research study of high school graduates from the years 1960-1965. Your help in providing data for this study has been most generous and invaluable.

The question that follows is very difficult for me to ask since I am a strong advocate of individual rights and I will certainly abide by your ultimate answer.

Will you please reconsider and give permission for me to obtain your transcript from the college you entered following graduation? You have my personal assurance that this data will be completely confidential. Reports of the research will not mention individual's names. All data is recorded in groups of about thirty individuals and will be reported as such.

Without your personal data, the final results of the research will be open to criticism that it did not achieve a true cross-sectional sample. Such criticism could seriously undermine the potential value of the study in improving American education.

A return envelope and permission form are enclosed. Please let me hear from you in a few days.

Sincerely,

Victor M. Showalter

VMS:ps

THE OHIO STATE UNIVERSITY
COLLEGE OF EDUCATION
DEPARTMENT OF UNIVERSITY SCHOOLS
29 W. WOODRUFF AVENUE
COLUMBUS, OHIO 43210

August 11, 1967

(Fourth follow-up letter to subjects who returned an incomplete long questionnaire - included page that was incomplete)

Dear ,

For one reason or another one page of the questionnaire you recently returned was incomplete. Enclosed is that page and a return envelope. Please complete the page and return it as soon as possible.

Sincerely,

Victor M. Showalter

VMS:ps

(plus hand written note of thanks)

THE OHIO STATE UNIVERSITY
COLLEGE OF EDUCATION
DEPARTMENT OF UNIVERSITY SCHOOLS
29 W. WOODRUFF AVENUE
COLUMBUS, OHIO 43210

August 10, 1967

(Third contact with selected subjects soliciting data for reliability test - included long questionnaire)

Dear ,

Have you heard about the new punctuation mark called the interabang? The interabang is intended to convey simultaneously the meaning of the standard exclamation and question marks. Its use does not require an answer since the answer is obvious. The interabang was invented specifically to follow phrases such as, "How about that‽" and "Another questionnaire‽"

The questionnaire that is enclosed is the same as the one you completed several days ago. Will you please complete the questionnaire and return it.

Thank you for your patience and generous contribution of your time.

Sincerely,

Victor M. Showalter

VMS:ps

THE OHIO STATE UNIVERSITY
School of Education
29 W. Woodruff Avenue
Columbus, Ohio 43210

(Fifth follow-up letter to subjects)

This letter is written as a reminder for you to complete and return the questionnaire that I sent to you recently.

You might be interested in some statistics of the study to date. Of the 287 individuals selected for the study, 256 have answered the first, short questionnaire. A total of 176 large questionnaires have been returned. As you can see, there is a need to boost the last figure.

Your questionnaire response is needed. Please do your best to find the time to finish it and send it back in the next day or two.

Sincerely,

Victor M. Showalter

VMS:ps

APPENDIX F

CATEGORIZATION OF FIRST-YEAR COLLEGE SCIENCE COURSES

TABLE XXVI

First-Year College Science Course Titles Categorized as Physical Science, Biological Science, or Social Science.

Physical Science

- General Chemistry
- Physical Geology
- Historical Geology
- Organic Chemistry
- Studies in Geology
- Natural Science
- Physics
- Elementary Astronomy
- Historical Science (geology)
- Elements of Engineering
- Physical Science and Civilization
- Principles of Geology
- Architectural Construction
- Architectural Design
- Evolution of Earth and Life (hours split with bio.)
- Descriptive Astronomy
- Physical Science
- Geology
- General Physics
- Chemistry
- Introduction to Physical Science
- Selected Topics in Physics
- Earth Science
- Introduction to Geology
- Principles of Physics
- Engineering Fundamentals
- Physical Science II
- Physical Science Core: Biology (hours split with bio. sci.)
- Explorations in Science-I (hours split with bio. sci.)

Biological Science

- Principles of Biology
- Principles of Microbiology
- Dendrology
- General Zoology
- Eugenics
- Principles of Zoology
- Introductory Biology
- Zoology
- Forestry (ag. dept.)
- Basic Biology
- Plant Science
- General Botany
- Introduction to Biology
- Life Science I: Principles
- Biological Science and Civilization
- Evolution of Earth and Life (hours split with phys. sci.)
- Biological Science
- Principles of Human Physiology
- Principles of Plant Biology
- Principles of Animal Biology
- Principles of Landscape Gardening
- The Living World
- General Biology
- Modern Biology
- Soil Conservation (ag. dept.)
- Advanced Botany
- Introduction to the Plant Kingdom
- Physical Science Core: Biology (hours split with phys. sci.)
- Natural Science (hours split with phys. sci.)
- Explorations in Science-I (hours split with phys. sci.)

Social Science

General Psychology
Elementary Psychology
General Anthropology
Introduction to Psychology
Introduction to Geography
General Sociology
Collective Behavior
Principles of Sociology
Geography
Psychology I
Cultural Anthropology
Economic Geography
American Society
Environment
Introduction to Cultural Anthropology
Introductory Sociology
Foundations of Human Behavior
Principles of Psychology
Educational Psychology
Psychology of Adjustment
Instroductory Psychology
Principles of Behavior
Dynamics of Human Behavior
Introduction to Cultural Anthropology
Freshman Studies in Anthropology
Social Trends and Problems
Educational Sociology
Culture
Social Science Core: Anthropology
Societies Around the World

APPENDIX G

SELECTIVITY RATINGS OF COLLEGES AND UNIVERSITIES

TABLE XXVII

Selectivity Ratings of Colleges Attended
by Experimental and Control Groups

KEY: MS = most selective
VS = very selective
HS = highly selective
S = selective
N = non-selective

COLLEGE	SELECTIVITY RATING
American College (Tours, France)	S
Antioch College	HS
Bliss Business College	N
Bluffton College	N
Bowling Green State University	N
Bryn Mawr College	MS
Butler University	S
California Institute of Technology	MS
Carnegie Institute of Technology	HS
Case Institute of Technology	HS
Central State College	N
Chaffey Junior College	N
University of Chicago	MS
Christian College	N
University of Cincinnati	S
Colorado College	VS
Colorado Women's College	S
Columbus Business University	N
Columbus College of Art and Design	N
Dartmouth College	MS
Defiance College	N
Denison University	HS
DePauw University	VS
Earlham College	VS
Eastern Kentucky State College	N
Harvard University	MS
Howard Junior College	N
College of Idaho	N
Kent State University	N
Kentucky Military Institute	N

COLLEGE	SELECTIVITY RATING
Kentucky State College	N
Kenyon College	HS
La Sierra College	N
Lindsey-Wilson Junior College	N
Massachusetts Institute of Technology	MS
Miami University	VS
Michigan State University	VS
Middlebury College	HS
Mitchell College	N
Muskingum College	S
North Central College	VS
Ohio College of Applied Science	N
Ohio Northern University	N
Ohio State University	N
Ohio University	N
Ohio Wesleyan	VS
Otterbein College	S
Parsons College	N
Queen's College (Ontario, Canada)	VS
Reed College	MS
Rio Grande College	N
Ripon College	VS
Saint Bernard College	N
Sarah Lawrence College	HS
Simmons College	VS
Stanford University	MS
Stephens College	N
University of Tennessee	N
Transylvania College	S
Urbana College	N
United States Military Academy	HS
Vassar College	HS
University of Virginia	VS
Virginia Intermont College	N
Washington State University	S
Wellesley College	MS
Wilmington College	N
Wittenberg University	VS
Wooster College	HS

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TITLE

EFFECTS OF A UNIFIED SCIENCE CURRICULUM ON HIGH SCHOOL GRADUATES

PERSONAL AUTHOR(S) John S. Richardson and Victor Showalter

INSTITUTION (SOURCE) The Ohio State University Research Foundation

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IDENTIFIERS

Ohio State University School, Unified Science Project

ABSTRACT

Possible long range effects of a four-year unified science curriculum in the high school were identified and evaluated. Specific effects were grouped in areas of (1) interest in science, (2) scientific literacy, (3) preparation for college science. The 358 subjects had graduated from high school four to several years prior to the study. Efforts were made to control variables such as intelligence, school achievement, school setting, sex, age, etc. Experimental treatment consisted of providing a new sequence of science courses based on interdisciplinary themes and content and that replaced the traditional course sequence. Data were obtained from high school and college transcripts and from a questionnaire constructed with assistance from 50 science educators. Findings indicated a general and consistent favorability for graduates from the unified science curriculum although the level of significance exceeded the arbitrary minimum in isolated cases only. Bibliography of unified science included.